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DEMONSTRATION OF THE LIMITATIONS AND EFFECTS OF WASTE DISPOSAL ON AN OCEAN SHELF

Raymond F. McAllister

Florida Atlantic Ocean Sciences Institute
Boca Raton, Florida

March 1968

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1 April, 1967 — 1 April, 1968

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Grant No. WPD 165-01 (R-1)-67

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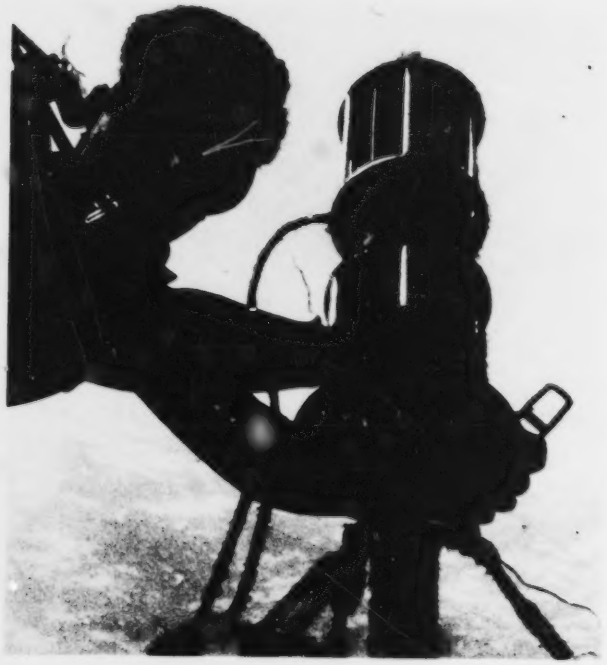

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Boca Raton, Florida

DEMONSTRATION OF THE LIMITATIONS AND EFFECTS OF WASTE DISPOSAL ON AN OCEAN SHELF

by

Dr. Raymond F. McAllister
Principal Investigator

March, 1968

Details of illustrations in this document may be better studied on microfiche.

ANNUAL PROJECT REPORT
For the Period 1 April, 1967 - 1 April, 1968

Submitted to the Federal Water Pollution Control Administration
Under Demonstration Project Grant Number W.P.D. 165-01(R1)-67

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Valuable consultation has been provided by many Florida Atlantic University colleagues but especially by Dr. Edward DeLamater, Dr. Glenn Waddell, Dr. Harrison Hoffmann, Mr. Eugene Robinson, and Dr. Richard Morgan. In addition to these men, Dr. Sheldon Dobkin and Dr. Richard Domey have participated as their busy schedule permitted.

Our thanks go to Dr. James Carpenter of John Hopkins University, without whose assistance our continuous flow fluorometer would have been totally unsuitable for marine use. Dr. Carpenter probably has no peer in the field of marine fluorometry. We are also indebted to Dr. William Richardson of Nova University who has on several occasions, as his busy schedule permitted, assisted us in our research.

Particular thanks go to our dedicated staff who all performed with excellence and, in most cases, carried a double work load without any hesitation or complaints. Mr. Robert Rosof, my project director, ran the field program, the Deerfield Beach Field Laboratory, and the business affairs of the project. Our staff has included the following: Douglas Briggs, Jay

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King Car Rentals of Deerfield Beach have been most patient, sharing their space with us for token rental, and Mrs. Hageman (Pal's Captain's Table Restaurant) has given us free dock space and access across her restaurant grounds.

The cities of Delray Beach, Boca Raton, and Pompano Beach in particular have been most cooperative in making space, engineering assistance, personnel and equipment available. We are especially indebted to Mr. Frank Hoble of the Pompano Beach Water and Sewer Department for assistance far beyond any reasonable expectation.

Mr. Del Hendrickson and the staff of UnderSeas Education, Inc., have made available their considerable marine knowledge and have loaned this project marine electronics equipment of considerable value and utility. It is fortunate that we have such good friends as USEINC in Fort Lauderdale.

To these and the many others not mentioned by name, take credit for all that is good in this report. The errors are mine.

Raymond F. McAllister
5 March 1968

INTRODUCTION

The area of this survey funded under the Federal Water Pollution Control Administration Grant W.P.D. 165-01(R1)-67 runs from just north of the Delray Beach, Florida, sewer outfall, approximately 5400 feet offshore in 90 feet of water, to just south of the Pompano Beach, Florida, outfall, 7400 feet from the beach in 90 feet of water, Figure 1. The coastal distance covered by the survey is about 16 nautical miles (nm) long by about 2 nm wide. A nautical mile is 6080 feet. The continental shelf of Southeast Florida is unique for the United States, and probably for the whole world, in that it is so narrow, and is adjacent to the Florida Current (popularly called the Gulf Stream), the earth's mightiest river, salt or fresh. This current, about 60 nm wide and 2500 feet deep flows at speeds up to 7 knots (1 knot= 1 nm/hr.), with 4 knots a good average, carrying 40 million cubic yards of water a second past Florida. This is more than 1000 times the volume of the Mississippi River and more than 50 times the flow of all the world's rivers put together.

The Gulf Stream, by virtue of its high speed is very turbulent and contaminants introduced into the Stream are soon mixed with unimaginable volumes of sea water. This current ofttimes flows close in to the Southeast Florida Coast, varying from a few hundred feet offshore to two to three miles, depending upon oceanographic conditions which are not known yet, and upon the particular definition of the Gulf Stream which is chosen. The edge of the Gulf Stream appears to shed eddies or vortices which rotate in the shelf water, or else to engender a variable inshore countercurrent part of the time. As a result, currents inshore of the Stream proper may flow either north or south and at speeds that decrease as the water shoals and bottom friction increases. Nevertheless, it is common to find 1 knot currents in water of

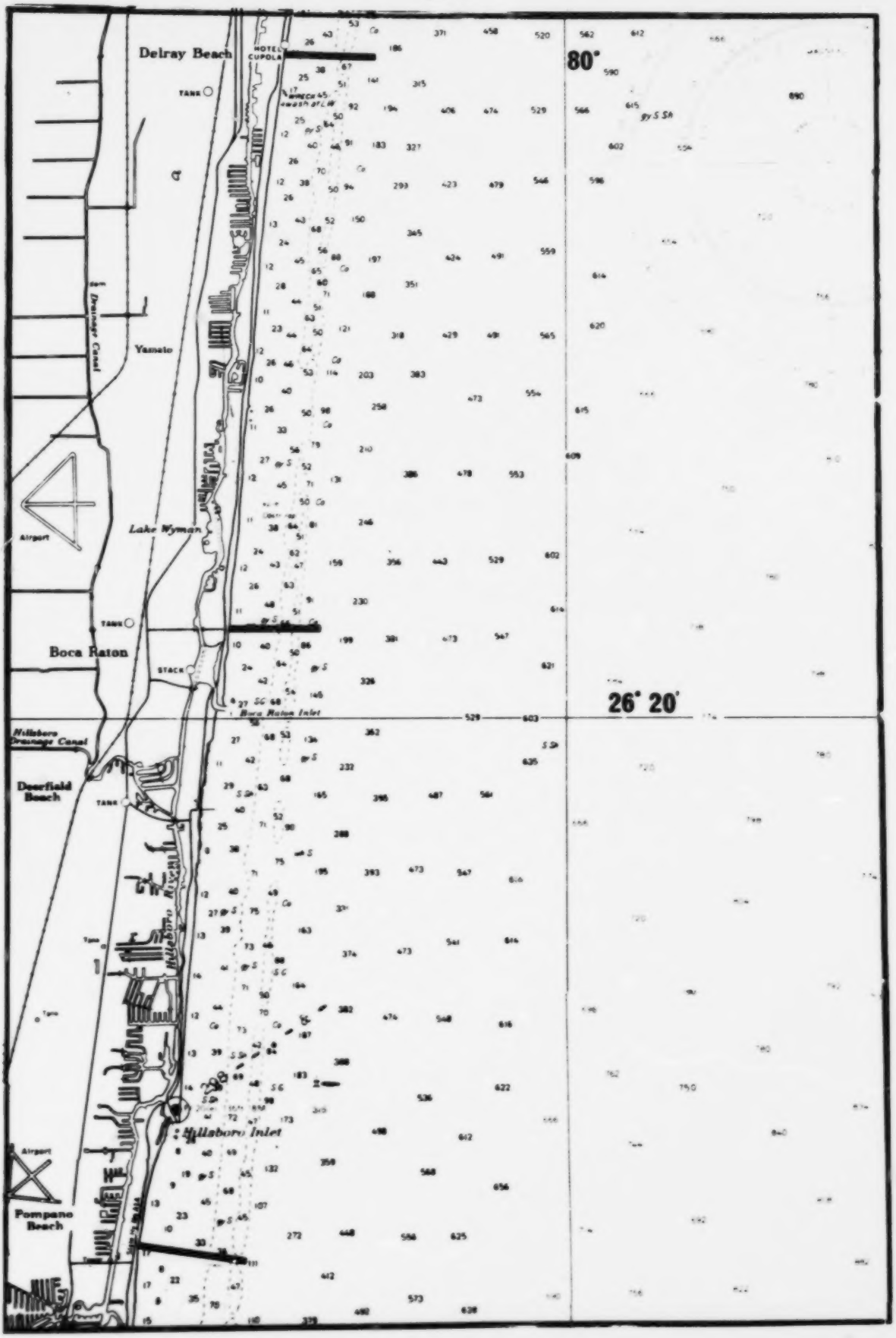

Delray Beach
HOTEL CUPOLA
TANK
80°
Yamato
Lake Wyman
Airport
Boca Raton
STACK
Boca Raton Inlet
26° 20'
Hillsboro Drainage Canal
Deerfield Beach
Hillsboro Inlet
Pompano Beach

FIG. 1

40-50 feet deep.

Parallel to the beach there are a series of reefs of worm rock and of coral. In many places the inner reefs are buried under sand from a few inches to several feet thick. Further offshore, a reef rises from the sand at about 80 feet to within 45 or 50 feet of the surface, then drops rapidly to more than 100 feet, after which the steep descent continues to deep water offshore. This reef acts as a modest barrier to east-west flow of water and as a trap for sediment, and helps channel currents into a north-south pattern. The prevailing practice is to run sewer outfalls through the 50 foot reef and have the pipes discharge effluent at about 90 feet, well down the slope from the crest of the reef.

At Delray Beach, a 36 inch outfall pipe delivers 1 1/2 million gallons of comminuted sewage, chlorinated for odor control, to the discharge point 90 feet underwater, approximately 5400 feet offshore, by gravity flow boosted by pumps. The design capacity is 11 million gallons per day. Settling tanks for sludge are not used. Sludge is continually pumped through the outfall system into the ocean.

At Pompano Beach, a 36 inch pipe discharges 2.4 million gallons a day of chlorinated and comminuted raw sewage and sludge to the outfall opening in 90 feet of water, 7400 feet offshore. Here, too, gravity flow is assisted by pumps. The Pompano Beach outfall end is shown in Figure 2.

An outfall is proposed for the city of Boca Raton, Florida, to be located as shown on Figure 1, and contracts have been let for its early construction. It will discharge comminuted and chlorinated sewage, free of floatables, in 90 feet of water beyond the 50 foot reef, which is about 5,000 feet from the beach in this area.

PROJECT OBJECTIVES (YEAR NO. 1)

Major objectives for the first year of this three year study are as follows:

1. To begin studies of the current regime on the Southeast Coast of Florida by means of current crosses (drift devices) and recording current meters.

2. To sample the microbiota of the water of the shelf, the adjacent Gulf Stream, and especially in the boil and down plume from the boil for

   a. coliform bacteria

   b. viruses as indicators of pollution

   c. planktonic organisms

      (1) as indicators of eutrophication or pollution

      (2) for future comparisons after the Boca Raton outfall is in operation.

3. By comparison of a number of samplings of 2. a., to begin to determine the distribution pattern for various current conditions and the speed of dieaway of coliforms and viruses in ocean water.

4. To collect (and classify as time and personnel permit) the fauna and flora of a transect from the beach at Boca Raton to the 130 foot depth, the limit for normal SCUBA diving. Particular attention will be given to the reef areas just north of the Boca Raton outfall site since this is the bottom area most likely to be affected by the effluent. Quantitative aspects of this study are difficult to assess but will be determined insofar as possible.

5. To make a particular study of the microbiota of the sediment-water interface at selected sites in the project area and to determine the significance of the forms found as indicators of pollution. This includes a study of the organisms attaching to slides placed at various depths and distances from the outfall.

6. To begin studies of the temperature structure, salinity, visibility, and various chemical indicators of organic enrichment of the ocean water. These studies may reveal unsuspected density stratification of the ocean, which could be significant. They will help reveal eutrophication near existing outfalls and provide a datum from which to determine the influence of the proposed Boca Raton outfall on the sea adjacent to it.

METHOD OF OPERATIONS

FACILITIES AND PERSONNEL

Shore Site

All operations are carried out from a shore station located in the Intracoastal Waterway, a few hundred yards south of Boca Raton, Florida. This protected site, safe from hurricanes, is convenient to the Hillsboro Inlet, to the ocean, to the Boca Raton Inlet, to Florida Atlantic University, and is about halfway between the cities of Delray Beach and Pompano Beach.

Boats

One or two small boats, about 20 feet long, are kept at this location and provide exceptionally inexpensive, fast and maneuverable platforms from which to work. Few operations require larger boats and these are cheaper to charter for a few days than to own and maintain. (During the first six months of the contract, when cable laying and current meter tower erection required it, a 41 foot vessel was assigned to the contract by the Florida Atlantic Ocean Sciences Institute. It is no longer required and has been released to save the higher operating and maintenance costs of a larger boat.)

Personnel

Most personnel of the project are able to fill all positions of a non-scientific nature and most of them are competent boatsmen, divers, optical tracking equipment operators, and can plot data in addition to their specialties;

marine biologist, electronics technician, machinist, wire rope and rigging specialist, construction engineer, oceanographer, etc.. The principal investigator and the associate project director are both thoroughly competent in, and engage in, the offshore operations and underwater work to insure complete supervision of all aspects of the program. Wherever possible samples are taken by divers, so that the exact location and depth of samples are known. Figures 3 and 4 show divers at work on specific parts of the project work. Some work can only be done by divers. Such items as sampling in the outfall pipe, and collection of all organisms on the reef to a depth of 4-6 inches under the coral, are examples of the latter. Divers and boatmen always work in pairs for safety.

Positioning

All locations are determined by optical control from carefully located shore points, providing accuracies to less than 6 feet at the maximum distance of operation offshore. Citizens Band radios keep the small boats in contact with the shore tracking stations. (Our call sign is KQP-3507.)

Cooperating Agencies

Samples for bacteriological studies are taken and kept viable according to instructions given by the Palm Beach County Health Department, and are picked up and run at the Florida State Board of Health Laboratory, in Lantana, Florida. The samples are analyzed according to "Standard Methods for the Examination of Water and Sewage". Salinities (actually chloride content-readily converted to salinity) have been run by the same laboratory.

Nitrates, B. O. D.'s, and D. O.'s have been determined for selected samples by the Pompano Beach Water and Sewer Department and this organization has provided various other services and space as required. Rhodamine dye injection will be done by their personnel as we indicate. The cities of

FIG. 4

Boca Raton and Delray Beach have provided space, engineering assistance, beach facilities, etc., whenever desired.

Virological studies are being performed at Florida Atlantic University where a graduate student and his supervising professor work in well equipped virology laboratories with backup assistance by Mr. Lawrence Lukin.

Dr. James Lackey, who is assisting and advising on many biological aspects of the program, has studied live samples within an hour of their collection in our Deerfield Beach laboratory, and preserved specimens in his home at Melrose, Florida.

In summary, a great deal of sampling and oceanographic study directed at achieving the project objectives can be and is being accomplished, at very low cost for boats and precise location, by intelligent use of available techniques and in consequence of the narrow shelf off Southeast Florida.

SAMPLING LOCATIONS

The samples taken at various stations are summarized by area as listed below. The secondary stations at Hillsboro Inlet and Boca Inlet have been occupied somewhat less often than desired, partly because, with the sudden natural closing of Boca Inlet last fall by sand moving south along the shore, it became a six foot high, 150 foot wide sand bathing beach, and no longer part of the survey. The Inlet was reopened in February, 1968, and it is planned to keep it open from now on.

Pompano Beach

A line of stations, from well inshore to substantially beyond the Pompano Beach outfall was occupied 78 times, and data was collected as tabulated in Table 1. Wind directions and speed, and barometric pressure, are recorded every four hours from the U. S. Coast Guard instruments at Hillsboro Lighthouse, at one of our secondary sampling lines.

AREA	BOCA	DELRAY	POMPANO	TOTAL
ECHO SOUNDINGS	835	595	744	2174
CURRENT CROSSES	1032	907	1320	3259
COLIFORM SAMPLES	260	344	434	1038
SALINITY SAMPLES	65	10	60	135
DIVES MADE	52	2	31	85
BOILS SIGHTED	0	12	31	43
SECCHI DISC READINGS	204	197	208	609

TABLE 1 DATA COLLECTED IN PROJECT AREA

In addition to the above, a number of dives and surface sampling runs were made to obtain samples of the plankton on the continental shelf and the fauna and flora of the sediment-water interface, and of the sediments a few inches below this interface for Dr. James Lackey. Copies of Dr. Lackey's reports are appended.

Boca Raton

The Boca Raton line has been occupied 53 times, with the results shown on Table 1. The large number of dives at Boca Raton reflects the pre-discharge sampling of the reef and sand bottom near the site of the proposed Boca Raton outfall. Here divers sampled staked out areas of the reef for quantitative faunal and floral distributions, and made a number of dives to erect the current meter tower, and to mount and maintain the meter. Many dives were two man dives; some, however, included as many as six men working on the bottom at the same time. 17 individual sampling stations on the bottom atop the "50 foot" coral reef were occupied, and the fauna and flora on and in the reef were sampled to a depth of 4-6 inches over an area approximately 2 feet square, Figure 3. These areas were chosen to represent all the visually different ecological zones and niches of this hard bottom. Sampling was quantitative, insofar as possible, since the objective was to determine, accurately, the distribution of living organisms of all phyla except the Chordata before the Boca outfall began discharge of effluent. A comparison could then be made with post-discharge conditions to determine the effects, if any, of sewage discharge on the bottom community. A map of the sampling areas is attached with an approximate profile across the reef, Figures 5 and 6.

In addition, when other operations permitted, a research collection of the plants and animals of the area was begun, with identification made by the project marine biologist and by marine scientists of Florida Atlantic

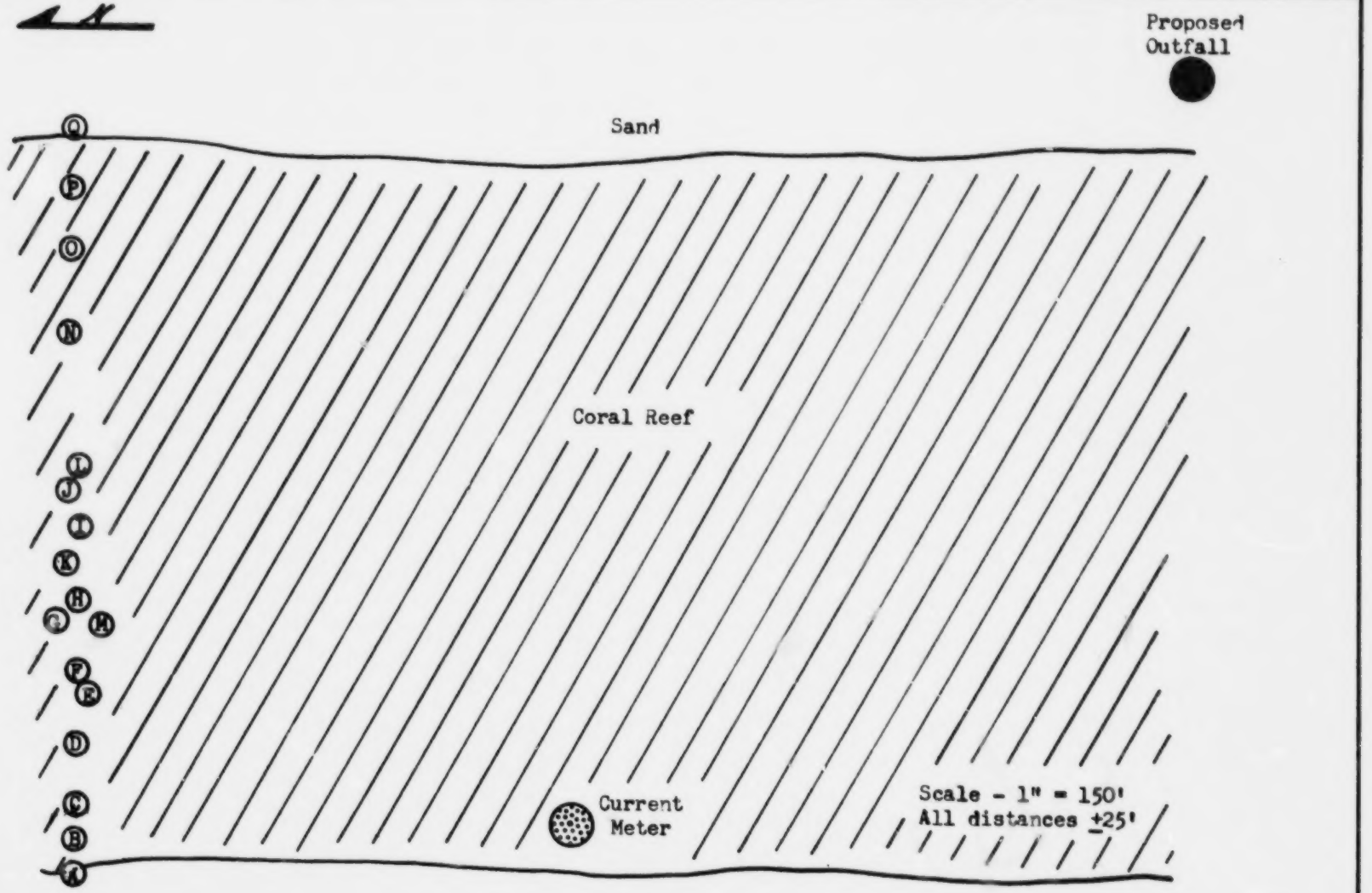


FIG.5

Reef Sampling Stations
Boca Raton

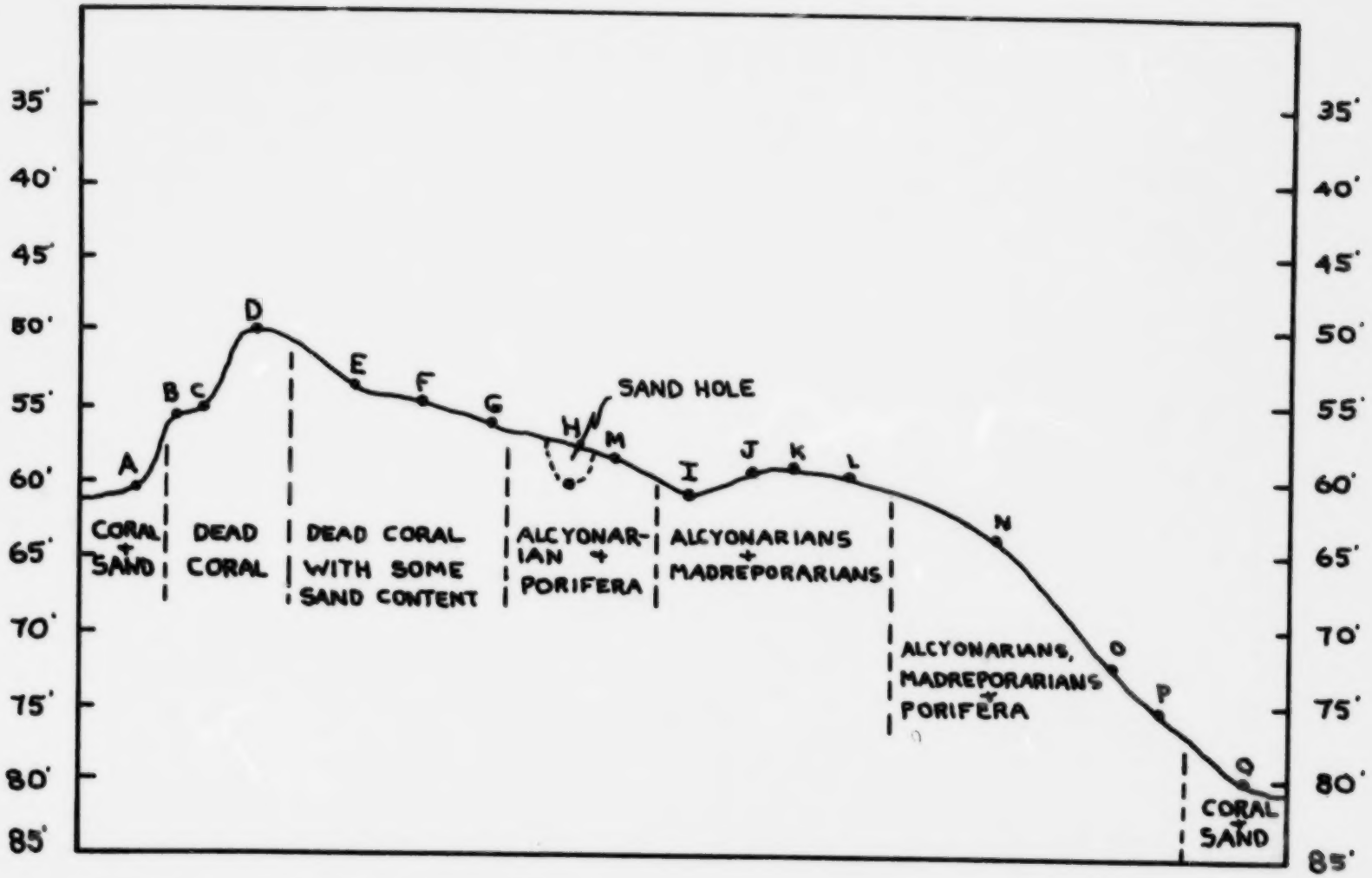


FIG. 6 CROSS SECTION OF BOCA RATON REEF

7a

University. Specialists on the staff of the Smithsonian Institution have expressed an interest in working with us, and Mr. Fehlmann of the Smithsonian Sorting Center will be visiting soon to assist us further.

Samples were taken in the Boca Raton area for Dr. Lackey who studied the microfauna of the shelf waters and also a limited number of Gulf Stream samples, taken far enough offshore to insure that no contamination by shelf plankton was likely. In addition he studied the fauna of the water very near bottom and the sediment surface, particularly looking for organisms which, in the past, he had found to indicate pollution or a high level of eutrophication.

The current meter installed at this location had operated continuously except for short periods, since the installation date of 19 September.

Delray Beach

The Delray Beach line of stations ran from near the beach to well beyond the outfall and was occupied 42 times. Results of these runs are compiled as Table 1. No current meter was installed at Delray Beach because maintenance problems made it imperative that one of the three meters procured commercially be used as a replacement for the two installed while they were cleaned and adjusted every ten days or so.

Special runs to the vicinity of the boil were made several times to check microbiological techniques, (see note below). Wind speed and direction and barometric pressure measurements were projected to this area from Hillsboro Lighthouse Coast Guard Station.

SAMPLING AND ANALYSIS PROGRAM

The sampling program has thus far produced a great deal of data, much of it very provocative. Brief discussion of some categories of data are given immediately below, and the important conclusions reached are covered in the following section.

Coliform Samples

Water samples for coliform counts are taken in containers provided by the Palm Beach County Health Department. In accordance with instructions, our personnel take surface water samples, on certain collection days, at the location of the initial current cross insertion, at selected subsequent stations and in the boil if it is sighted. The samples are kept out of the hot sun in an ice chest, but no ice or other cooling agent is used. They are picked up by the representative of the Health Department, and from time to time the senior technician from that group goes to sea with us to assist in and supervise sample collection.

According to the Health Department, samples are picked up and carried to the home of the technician where they are stored in his icebox or refrigerated in the ice chest in his garage. All samples are normally run sometime the next day by the millipore filter method in accordance with "Standard Methods", with no dilutions, in order to determine the most probable number (MPN) of coliforms per 100 cc of water. See Appendix for Board of Health plots of coliform counts in the areas of the project.

When it was noted that few or no counts occurred, even in samples from the boil, the procedure was questioned and a number of samples were taken in sterile quart jars, shaken thoroughly and split. One half of the splits went to Public Health by the same route as usual, run sometime the next day. The other half was taken to Dr. Hoffmann who desired some comparison samples for his University contract with Pompano Beach. We made the following comparison on the splits. See Table 2 and Figure 7.

The State Board of Health Laboratory used the 5 tube lactose broth method in accordance with "Standard Methods", with confirmation on brilliant green, and diluted to .001.

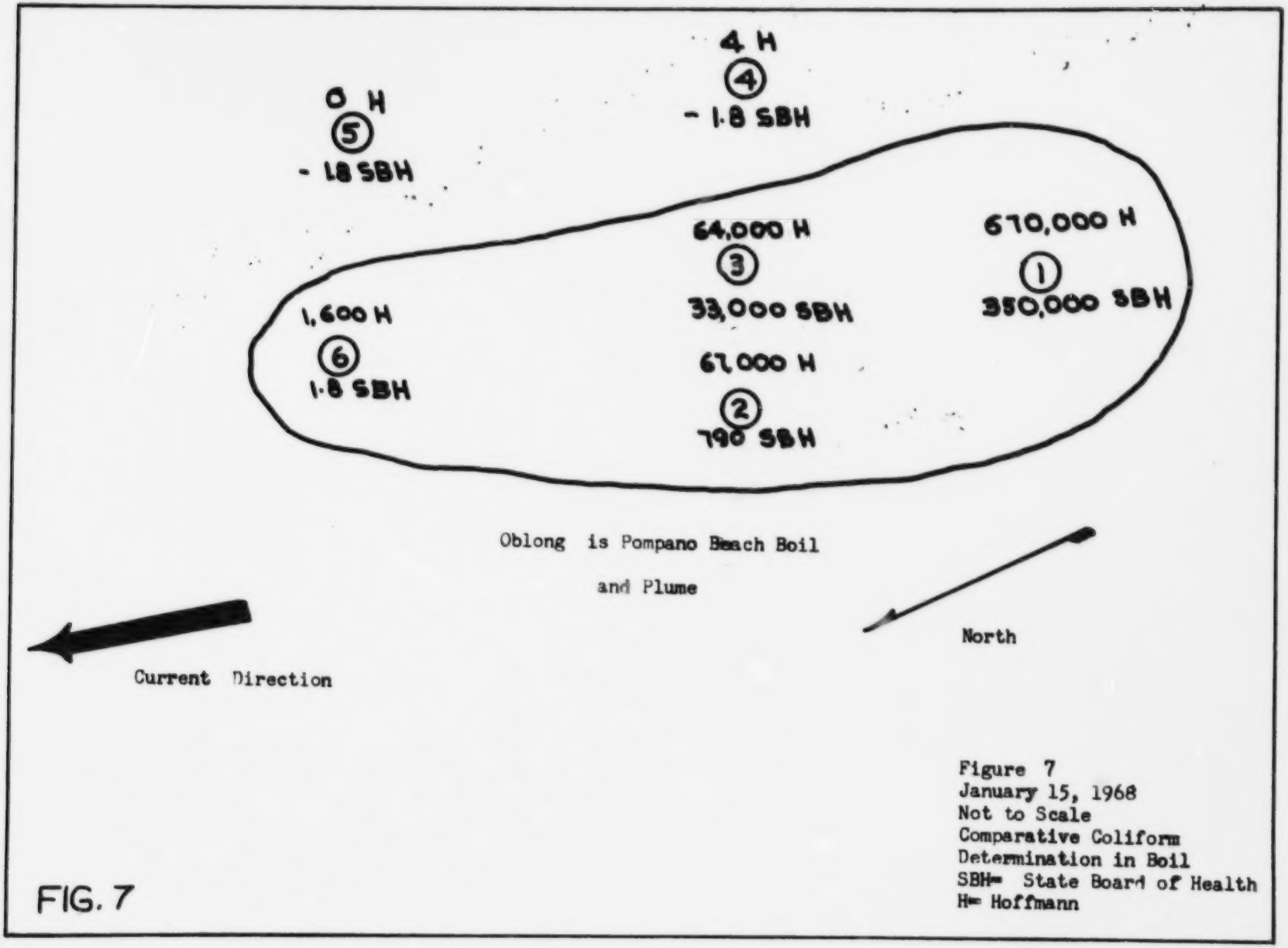


FIG. 7

Figure 7
January 15, 1968
Not to Scale
Comparative Coliform
Determination in Boil
SBH= State Board of Health
H= Hoffmann

TABLE 2

SAMPLE NUMBER	DATE	LOCATION OF SAMPLE	COLIFORM COUNT SBH*	COLIFORM COUNT Hoffmann**	REMARKS
1	1/15/68	Pompano Boil	350,000	670,000	In Boil
2	1/15/68	Pompano Boil	790	67,000	270 feet North of Boil
3	1/15/68	Pompano Boil	33,000	64,000	330 feet North East of Boil
4	1/15/68	Pompano Boil	-1.8	4	400 feet East North East of Boil
5	1/15/68	Pompano Boil	-1.8	0	600 feet North East of Boil
6	1/15/68	Pompano Boil	1.8	1,600	540 feet North North East of Boil

* State Board of Health Laboratory, Lantana, Florida

** Dr. Harrison Hoffmann, Florida Atlantic University, Boca Raton, Florida

Dr. Hoffmann used the millipore filter method with 5 dilutions (to 100,000) and sterile phosphate buffer according to "Standard Methods". The two methods should give essentially comparable results. The discrepancies existing are being investigated and will be reported on in the next contract year.

Further studies of the microbiology are being made by Dr. Hoffmann and one of his graduate students, who are using the samples to study a variety of bacteria in a nearshore marine environment, for comparison with his Pompano Beach studies. It is expected that his studies will eventually show whether other bacteria than the coliforms will serve as indicators of pollution and will provide background for the Boca Raton area when the Boca outfall comes on line.

Virology

The virus studies have thus far centered around the use of bacteriophage F2 as an indicator of fecal contamination from the ocean outfall systems. Determinations of the longevity of bacteriophage F2 have been made, as well as the determination of the background bacteriophage population in both the Boca Raton settling tank and the surface boil from the Pompano Beach ocean outfall.

Bacteriophage F2 was shown to be useful in these early virus studies as the agent for the marker contaminant. Experimental results have indicated that wild type Escherichia coli phages do not infect the E. coli K-12 strain employed for the assay of the F2 phage; nor does the F2 phage infect the wild type E. coli normally found as a human fecal constituent. Samples of water obtained from both the Boca Raton sewage settling pond and the ocean outfall boil, and near areas, did not reveal the presence of phage capable of infecting the K-12 strain of E. coli.

Experiments have been conducted to determine the die-out, or inactivation, of the F2 phage under conditions simulating the natural environments under which future testing will be conducted. Samples of pond water obtained from the Boca Raton sewage treatment plant innoculated with the F2 phage at a concentration of 1×10^7 pfu/ml (plaque forming units per milliliter) resulted in a die-out of 2 logs of virus in a period of six days. Similar samples of this same water filtered through a millipore filter (0.22 micron) to remove macromolecular constituents, resulted in a decrease of 4 logs of virus in an equal period. These results indicate that the macromolecular constituents in sewage have a considerable protective effect on viruses. This finding also points out the importance of employing viruses as indicators

of pollution. Similar experiments conducted with sea water samples obtained from the boil of the Pompano Beach ocean outfall system revealed a loss of only one log of virus the first day and a total of four logs of virus over a six day period.

Preliminary results employing dialysis bags as containers for the bacteriophage preparation have indicated a complete die-out of phage when immersed in sea water for a period of four days. Three logs of virus were inactivated the first day. Further experiments, simulating the more natural sea water environment, show no initial osmotic shock effect of sea water on the F2 phage.

In order to facilitate recovery of phage F2 when injected into the ocean outfall system it would be desirable to take advantage of dye marker studies planned. Therefore, experiments were conducted to determine the effects of the rhodamine dye to be used on the F2 phage. Although these experiments are not complete, we can state that rhodamine dye has no deliterious effect on F2 phage in concentrations as low as one part per thousand. The fluorometer is capable of detecting this dye in concentrations as low as one part per billion or less. The lack of an effect on the F2 phage by this dye will greatly facilitate the determination of the pattern of sampling for virus injected into the ocean outfall system and followed downcurrent.

It is thus apparent that bacteriophage F2 may be utilized effectively as an indicator for the determination of fecal contamination in the ocean. The results obtained, employing the F2 phage as an indicator, will greatly facilitate studies involving viruses normally eliminated in fecal material from the human population. The protective effect of macromolecular materials

on the F2 phage, as shown by our studies, is of great importance, for under this protective effect the longevity of viruses in fecal material may be increased drastically. The importance of increased longevity of viruses is obvious to the student of distribution of pollutants. We anticipate the determination of the effects of macromolecular constituents found in fecal materials on representative animal viruses, in the very near future. In particular, those viruses known to be eliminated in human wastes shall be studied. See Dr. Waddell's complete report in Appendix for figures and tables.

Plankton Studies

Plankton samples have been taken for Dr. Lackey both by dipping up water mixed well at the ocean's surface, bottling it and keeping it in the shade until delivered to him, or by collecting and preserving all organisms in formalin for his later study. A number of plankton net tows have been made to collect large representative samples, both in nearshore waters, and far offshore where the Gulf Stream water is free of possibility of shore contamination. Five gallon samples of water are taken occasionally and left to sediment in the dark after preservatives are added. This insures collection of adequate numbers of undamaged forms for identification. Dr. Lackey's reports are appended.

Sediment-Water Interface Studies

Samples taken by short pushcorers have been provided to Dr. Lackey from areas which he has preselected, Figure 8. The organisms of this interface zone are removed, prepared and identified by Dr. Lackey. Counts of major forms and particularly of indicators of high organic levels are made. The diver obtained samples insure that desired environments are

FIG. 8

sampled and permit bottom observations to go with each sample. A number of interesting phenomena have been observed and further data is being collected by Drs. Lackey and McAllister for a paper on the binding of bottom sediments by a dense algal mat, not noted before divers began observing underwater. Certain exciting relationships between interface forms and depth of water are beginning to become apparent. The paucity of pollution indicating forms is noteworthy.

A few samples of the sediment-water interface in the inlet will help appraise the effect of inlets on the pollution of the nearshore ocean, in order to assess the respective roles of inlets and outfalls.

Seawater Chemistry: B.O.D.'s, D.O.'s, and Nitrates

Divers carrying clear plastic tubing have taken a number of water samples at predetermined depths for biological oxygen demand, for dissolved oxygens, and for nitrate determination. In addition several samples have been taken in the mouths of the two existing outfalls to determine the nature of the effluent, its salinity, its temperature, and its B.O.D.. All of the plastic tube samples are obtained by holding the tube open in the flowing water to insure good flushing, then corking it with rubber stoppers. Done underwater, this insures a good sample of the water exactly at the chosen depth, a well flushed sampler, and no gas bubbles in the material sampled. Results are depicted in Tables 3 and 4.

Outfall Boil Observations

On every trip the presence of a sewage boil at the surface is sought. Its extent and the associated odor is noted. Tables 5 and 6 chart the pertinent details of boil observations. In general, pronounced boils are not found at times of high currents. By the time the effluent reaches the

14b

TABLE III

D.O., B.O.D. and NO_3

Pompano Beach, Florida

Location Number	Date	Depth	D.O. mg/l	B.O.D. mg/l	NO_3 mg/l
21	11/6/67	Surface			-0.01
21	11/6/67	30 feet			-0.01
21	11/6/67	55 feet			-0.01
21	11/6/67	Unmarked			-0.01
21	11/20/67	Surface			-0.01
21	11/20/67	30 feet			-0.01
21	11/20/67	55 feet			-0.01
21	12/7/67	Surface			-0.01
21	12/7/67	30 feet			-0.01
21	12/7/67	55 feet			-0.01

NOTE: -0.01 indicates less than 0.01

TABLE 4

D.O., B.O.D. and NO_3

Boca Raton, Florida

Location Number	Date	Depth	D O. mg/l	B.O.D. mg/l	NO_3 mg/l
34	7/12/67	20 feet	5.4		
34	7/12/67	30 feet	7.2		
34	7/12/67	52 feet	10.2	1.4	
34	7/13/67	Surface	6.4	2.0	
34	7/13/67	30 feet	6.4	0.6	
34	7/13/67	50 feet	6.4	0.7	
34	8/15/67	Surface	6.2	0.5	
34	8/15/67	15 feet	5.6	0.1	
34	8/15/67	30 feet	6.0	0.5	
34	8/15/67	50 feet	5.8	0.4	
31	8/24/67	Surface	5.8		
31	8/24/67	20 feet	5.8		
31	8/24/67	30 feet	5.8		
31	8/24/67	55 feet	5.6		
34	9/6/67	Surface	5.2		
34	9/6/67	20 feet	6.2	0.4	
34	9/6/67	35 feet	5.6	0.2	
34	9/6/67	50 feet	5.8	0.4	
31	9/15/67	Surface	6.1	0.5	
31	9/15/67	20 feet	7.0	0.5	
31	9/15/67	55 feet	6.8	0.7	
31	10/26/67	Surface	6.2		
31	10/26/67	30 feet	6.3		
31	10/26/67	52 feet	6.8		

DATE	BOIL SIGHTED	CURRENT SPEED IN KNOTS	CURRENT DIRECTION	ODOR	REMARKS
5/18/67	No	0.3	S	None	
5/19/67	No				
5/20/67	No				Small amount of toilet paper near current meter
5/25/67	No	0.6	S		
5/27/67	No				Some pieces of toilet paper
6/2/67	No	0.9	S		
6/8/67	No	0.5	NW		
6/15/67	No				
6/23/67	No				
6/24/67	No				
6/29/67AM	No	1.2	N		
6/29/67PM	No	1.1	N		
6/30/67	No				
7/5/67	No	1.2	N		
7/6/67AM	No				
7/6/67PM	No				
7/6/67PM	No				
7/11/67AM	No	1.0	N		
7/11/67PM	No	1.0	N		
7/12/67	Yes			Strong	40 yds Diameter
7/18/67	No	.8	S		
7/24/67	Yes				
7/25/67	Yes				100 yds North of outfall
7/31/67	Yes	.1	SW		
8/3/67	No	.8	NW		
8/9/67	No	.6	S		
8/14/67	No	.7	N		
8/14/67	No	1.3	N		
8/18/67	No	.9	N		
8/21/67	No	.5	S		
8/29/67	No	.7	SE		
8/30/67	Yes				
9/7/67	No	.4	S		
9/15/67	Yes	.3	N	Strong	Pronounced
9/20/67	Yes	.4	N		
9/29/67	No	1.0	N		
9/30/67	Yes	.25	W		Paper and Feces
10/3/67	Yes	.6	S		
10/13/67	No	.6	S		
10/16/67	Yes	.7	S	Weak	100' in Diameter - Many floatables very pronounced
10/18/67	No	.4	N		
10/19/67	Yes			Moderate	L 100' W 25'
10/23/67	Yes	.5	NW	Strong	
10/24/67	Yes		N		

TABLE 5 BOIL SIGHTINGS - POMPANO

DATE	BOIL SIGHTED	CURRENT SPEED IN KNOTS	CURRENT DIRECTION	ODOR	REMARKS
10/25/67	No		N		
11/1/67	Yes				
11/2/67	No	.9	N		
11/6/67	No	.2	S		
11/14/67	No	.2	N		
11/15/67	No				
11/24/67	No	.6	N		
11/28/67	Yes	.7	S	Strong	2 Boils 78° Temp Very Pronounced
11/30/67	Yes				
12/4/67	Yes	.8	SW		78° F in Boil
12/6/67	No	.5	NW	Moderate	Birds working
12/18/67	No	.4	N		
12/20/67	No	.3	N	Moderate	Some material
1/3/68	Yes	.6	N		Pronounced
1/3/68	Yes		N		Very Pronounced
1/5/68	No	.4	N		
1/11/68	Yes				Pronounced
1/12/68	Yes	.7	SW		Many Birds
1/15/68	Yes	.2	S		Many Birds
1/25/68	No	1.2	N		
2/1/68	Yes	.2	NW	Very Strong	
2/6/68	Yes	.4	S		Very Pronounced
2/8/68	Yes				Birds Working
2/13/68	Yes	.1	No Defined Direction	Present 1000' from Boil	
2/19/68	Yes			Strong	Birds Working
2/20/68	Yes	.7	N		
2/21/68	Yes				2 Boils Very Pronounced
2/22/68	Yes				
3/1/68	No	.4	N		Some Paper Birds Working

TABLE 5 (CONT.)

DATE	BOIL SIGHTED	CURRENT SPEED IN KNOTS	CURRENT DIRECTION	ODOR	REMARKS
5/24/67	No	.2	E		
5/26/67	No				
5/29/67	No				
5/31/67	No	1.0	N		
6/6/67	No	.4	NW		
6/20/67	No	1.0	N		
6/22/67	No	.4	NW		
6/28/67	No	1.0	N		
6/28/67	No	1.0	N		
7/11/67	No	.6	N		
7/12/67	No	.4	NW		
7/19/67	No	1.2	SW		
7/19/67	No	.3	SW		
7/28/67	Yes	.9	N		
7/28/67	Yes	.2	NW		
8/1/67	No	.8	S		
8/2/67	No	.5	N		
8/7/67	No	.7	N		
8/10/67	No	.6	N		
8/16/67	No	1.2	N		
8/17/67	No	.7	N		
8/24/67	No	1.1	N		
9/1/67	No	1.6	N		
9/5/67	No	.3	N		
9/11/67	No	1.4	N		
9/21/67	No	.7	NE		
9/26/67	No	.3	NE		
10/10/67	Yes				
10/12/67	No	.6	NNW		
10/19/67	No	.5	NW		
10/27/67	No	.5	NW		
11/2/67	No	1.0	N		
11/16/67	No	.2	NW		
11/22/67	Yes	.5	N	Strong	60' Diameter
11/27/67	No	1.3	N		
12/1/67	No	.3	NW		
12/5/67	Yes				Not Pronounced
12/13/67	Yes	.3	NW		
12/18/67	No	1.0	NW		
12/27/67	Yes	1.0	N		Much Sewage
1/2/68	Yes	.7	N		Very Pronounced
1/22/68	Yes	.4	SSW		
1/31/68	Yes	.2	SW		
2/12/68	Yes	.2	NNE		Very Weak
2/22/68	Yes				
2/26/68	Yes			Strong	

TABLE 6 BOIL SIGHTINGS - DELRAY

surface it has been highly diluted. For example, salinities in the mouth of the sewer pipe 90 feet underwater are about 1 °/oo. At the surface in the boil, taken 2-3 minutes later, salinities are about 36 to 36 1/2 °/oo, the normal salinity of Gulf Stream water. To all intents and purposes the salinity (and temperature) show dilution to normal oceanic conditions in 90 feet of rise.

Nonetheless, the boil is present on many days in the winter, Figure 9 and occasionally in the summer. It is offensive if you are directly in it and realize what it is. Sometimes the odor can be strong, much as it is downwind of a sewage treatment plant. Generally the odor is confined to the boil area itself. Seagulls "work" the boils when they are prominent and they constitute offensive indicators of pollution, but again, only in the immediate vicinity. It is doubtful that anyone on the beach ever suspects the presence of a sewage boil offshore. The plumes of comminuted sewage extend for varying distances from the boil but are seldom, if ever, visible 1000 feet downcurrent.

Diver observations of the bottom adjacent to the outfalls show no significant effects (visible) on the reef or around the outfall, except possibly the pileup of cigarette filter tips on the bottom between periods of rough waters. Apparently no sludge settles to the sea floor in these two areas and no other solids or "floatables" appear to be caught on sea fans or other organisms or on our current meter guy wires.

Reef Sampling for Macrobiota

To determine the ecology and the quantitative aspects of reef life in the proposed area of the Boca Raton outfall, bottom locations have been marked out on the reef just north of the proposed Boca Raton outfall. The location

of the proposed Boca Raton sewer mouth is indicated in Figure 10. Figure 5 shows a view of the reef and sample area, and Figure 6 a cross section. Two diver tows along the entire length of the line from reef to beach have been made and specimens collected from the surface of the sand. The sand infauna will be studied as soon as the more significant reef sampling is complete.

Areas of the reef about 2 feet square, have been selected by Dr. McAllister after consultation with a bio-statistician, an invertebrate marine biologist and an algologist. Each area represents, insofar as can be determined underwater, either a differing suite of organisms, a different biotope or biogeological environment, or a significant difference in water depth. Divers collect all forms on the surface and place them in plastic bags to bring to the surface. Then the bottom "coral" to a depth of about 4-6 inches is removed and when returned to the laboratory, broken open and all boring infaunal forms collected. This is a laborious task but clearly necessary to a study of the effects of a future outfall on the life of the reef since so much reef life is subsurface. For details, see Appendix - Reef Sampling Program, by Terry Davis.

Vertebrates are excluded from this study because of the great difficulty of collecting a representative sample. Nonetheless, a study should be undertaken of the concentration of pollutants in the bodies of fish which invade outfall pipes and which swim repeatedly through the sewage plume. Many of these are, no doubt, thigmotrophic, and hover near the protruding pipe as they would near any underwater structure which provides cover for them and distraction to their enemies. Some, however, might possibly be sewage feeders.

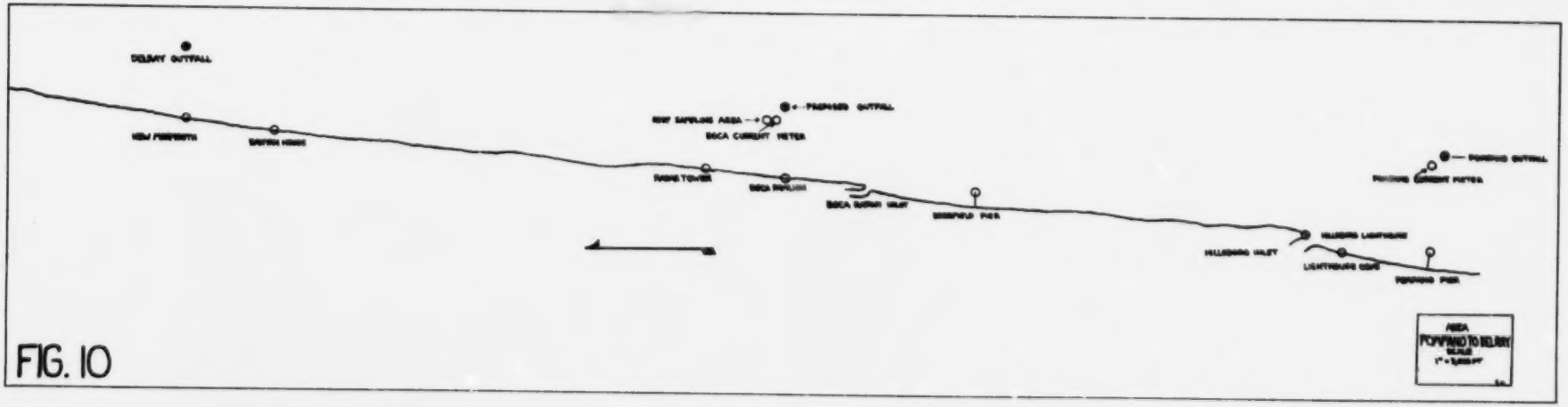

DELRAY OUTFALL
NEW RIVER
SANTA ROSA
RIVE TOWER
BOCA INLET
BOCA RATON INLET
DEERFIELD PIER
HILLSBORO INLET
HILLSBORO LIGHTHOUSE
LIGHTHOUSE POINT
POMPANO PIER
AREA
POMPANO TO DELRAY

FIG. 10

Current Studies

These studies are broken into two groups with a third to be added, on a no additional cost to the project basis.

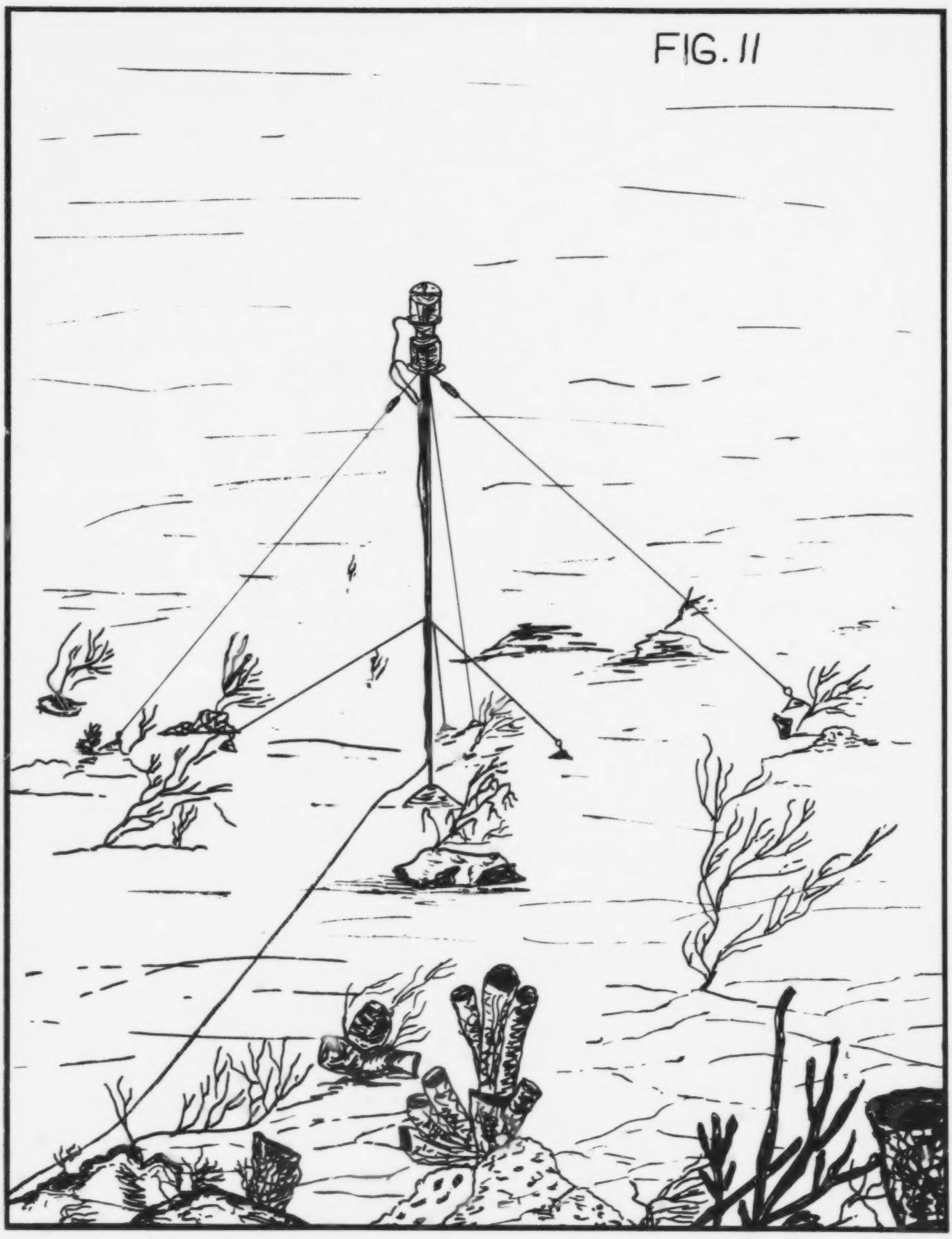
Current Meters

Two recording current meters, of three purchased for the purpose, have been installed 26 feet underwater on top of 30 foot high pipe towers in 56 feet of water. One is just inshore and a short distance north of the Pompano Beach outfall, and the second just north and inshore of the proposed Boca Raton outfall. The towers are of steel 2 inch galvanized pipe cemented into the reef by our divers, and guyed to ring bolts cemented into the reef as well, Figure 11. Both towers have withstood several severe winter storms and in one case, snagging by very heavy fishing tackle on a 150 pound test steel wire. A lobster pot was apparently dragged across one tower which damaged the current meter. Figure 4 shows the tower being built.

The towers put the current speed and direction meters as close to the surface as we deemed prudent, yet well away from bottom friction effects. It is felt that the current at 26 feet is essentially the same as at the surface, based upon current cross studies. Double armored steel cable was run from the top of the tower to the beach where a shore recording package was placed. All cable laying and splicing, as well as construction of the tower was done "in house".

Before the third meter could be connected, it was discovered that the combination of heavy fouling by organic growth, snagging by fishing lines, and general undependability of the current meters required that one of the three units be constantly available to replace a fouled or damaged meter. Nevertheless, the two recording meters have shown a pattern of speed and

FIG. 11



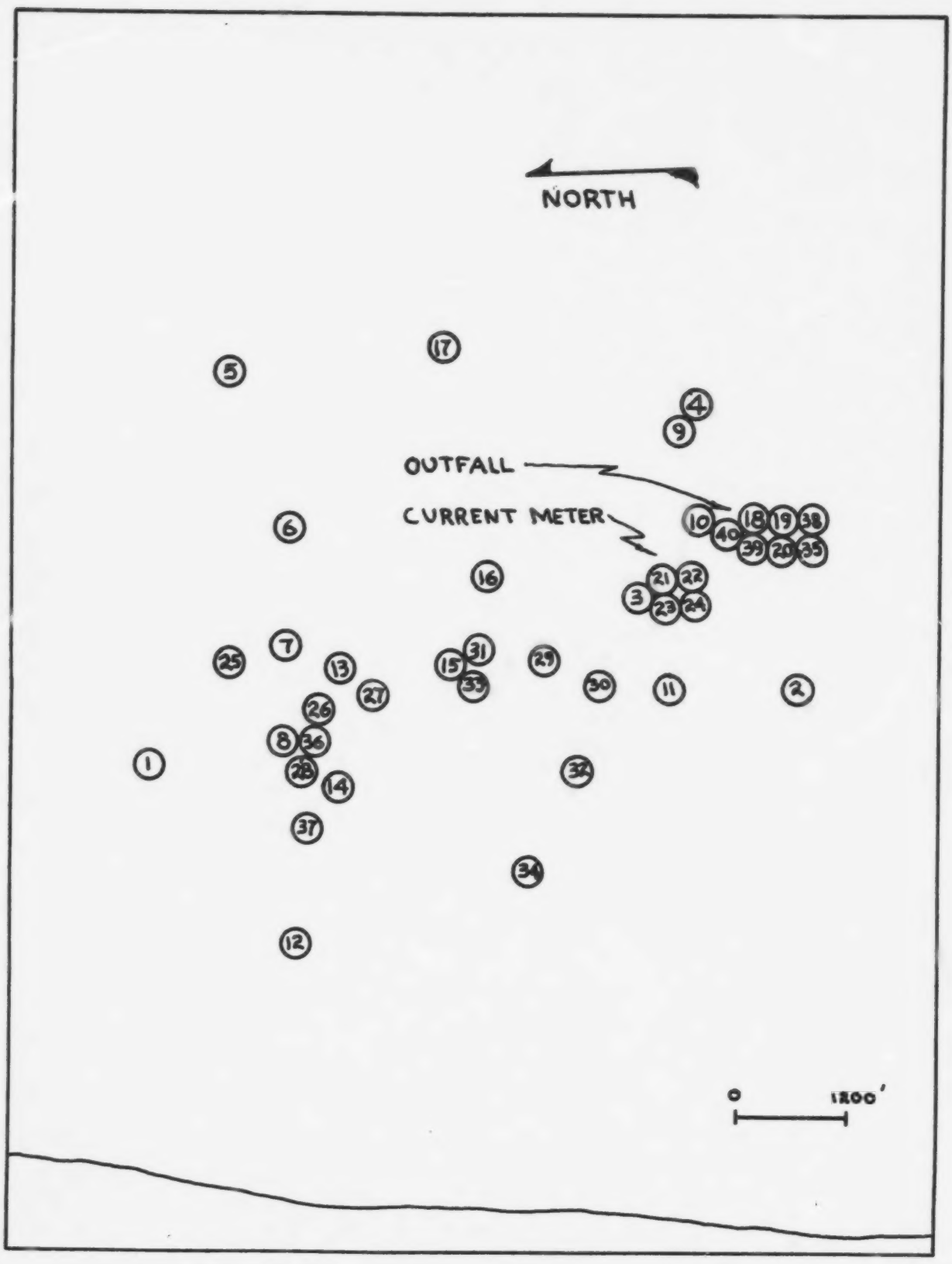


FIG. 12 — SALINITIES - POMPANO BEACH AREA

direction requiring more than casual analysis to understand. Current may be south at Boca Raton, and north at Pompano Beach. This suggests eddies inside the Gulf Stream. Abrupt changes in direction as shown in Figure 12 suggest some sort of cyclic component to the currents, but unfortunately they are apparently not of tidal period. Correlation with the winds cannot be made either.

The current meters are best for indications of direction, since the direction vane almost never fails, and poorest for speed, since the Savonius rotor speed unit is not at all dependable. In consequence measurements with drift devices are particularly important to supplement recording current meter observation. Figure 13 is a small section of the Esterline Angus recorder record of currents.

Drift Measurements

1. Current Crosses, Figure 14, were used in the outfall areas, to measure the water particle trajectories, first at the surface and then both at the surface and at various depths underwater. One magic depth was 26 feet to give correlation with the recording current meter as the current crosses passed the current meter location.

The problem of current cross studies are many and the difficulties of correlating them with recording current meter data, etc., are well known. Nevertheless, much useful information has come out of the current cross studies. Since they were designed to respond primarily to water motion and to be nearly unaffected by air currents (wind), the meters show the sort of trajectories that we might reasonably expect for sewage in the water at the various depths of measurement but primarily at the surface.

Figure 15 also shows representative current cross plots.

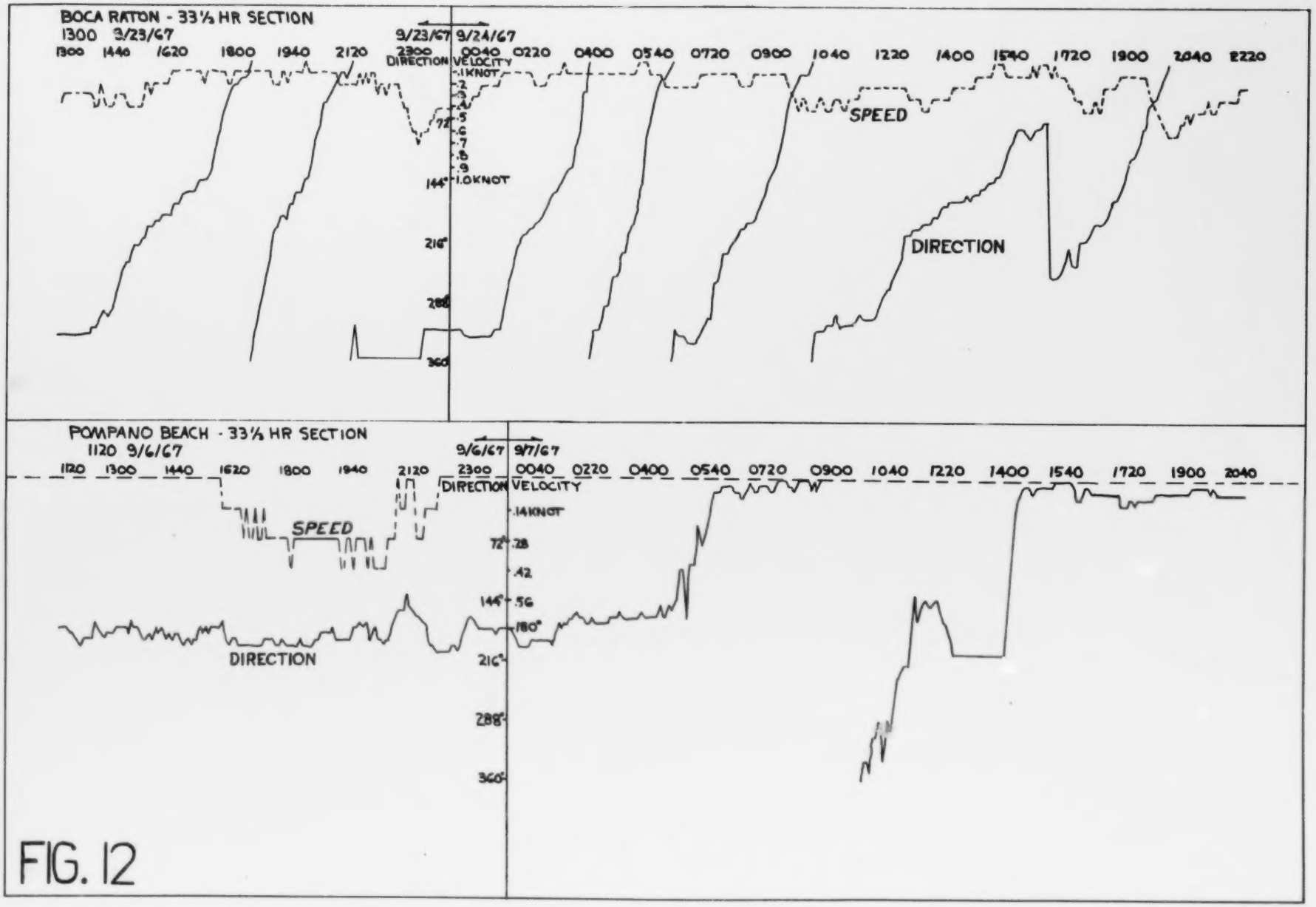

BOCA RATON - 33⅓ HR SECTION
1300 9/23/67
1300 1440 1620 1800 1940 2120 2300 0040 0220 0400 0540 0720 0900 1040 1220 1400 1540 1720 1900 2040 2220
9/23/67 9/24/67
DIRECTION
VELOCITY
.1 KNOT
.2
.3
.4
.5
.6
.7
.8
.9
1.0 KNOT
72°
144°
216°
288°
360°
SPEED
DIRECTION
POMPANO BEACH - 33⅓ HR SECTION
1120 9/6/67
1120 1300 1440 1620 1800 1940 2120 2300 0040 0220 0400 0540 0720 0900 1040 1220 1400 1540 1720 1900 2040
9/6/67 9/7/67
DIRECTION
VELOCITY
.14 KNOT
.28
.42
.56
72°
144°
180°
216°
288°
360°
SPEED
DIRECTION

FIG. 12

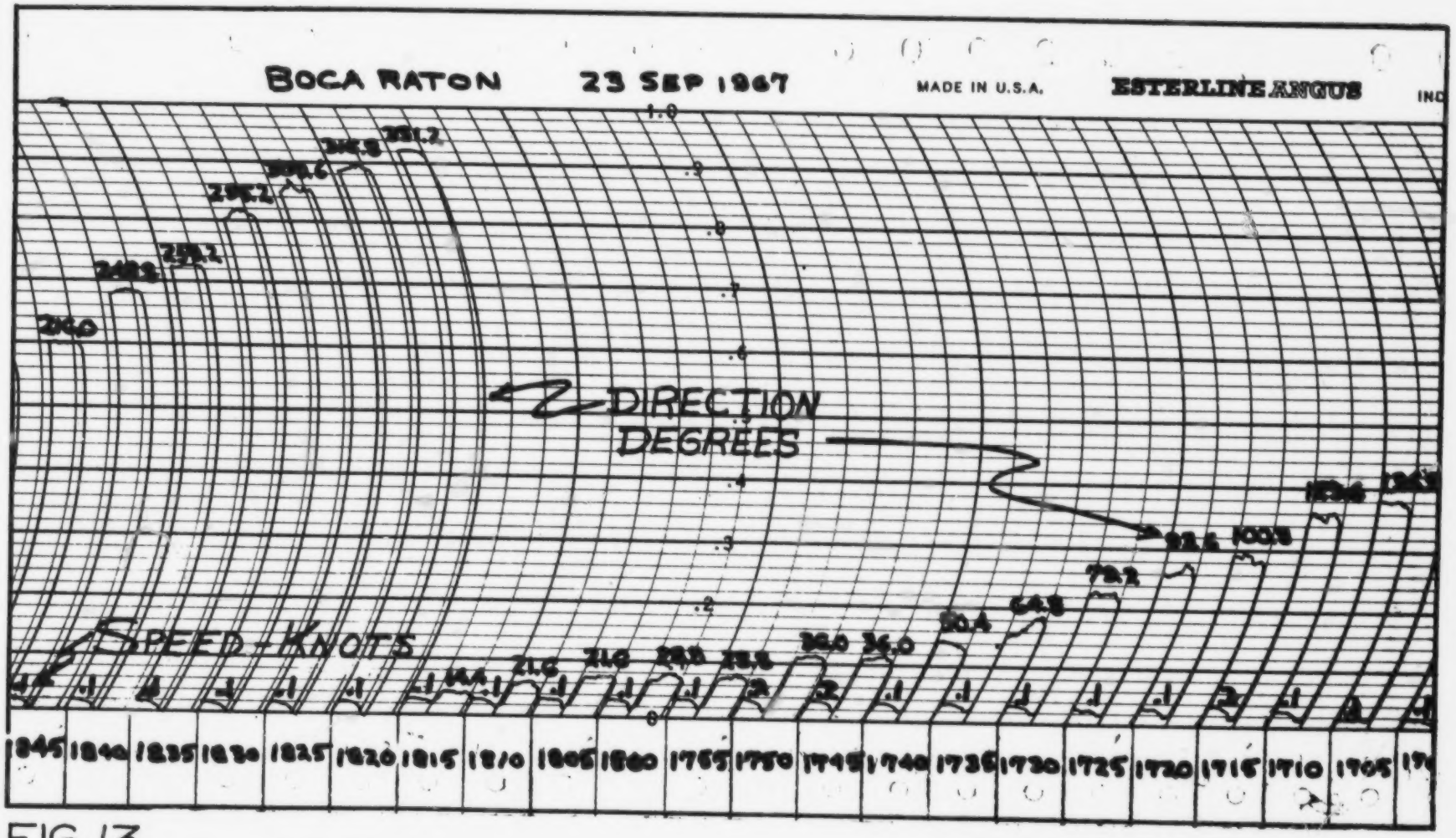

BOCA RATON
23 SEP 1967
MADE IN U.S.A.
ESTERLINE ANGUS
DIRECTION
DEGREES
SPEED - KNOTS
1845
1840
1835
1830
1825
1820
1815
1810
1805
1800
1755
1750
1745
1740
1735
1730
1725
1720
1715
1710
1705

FIG. 13

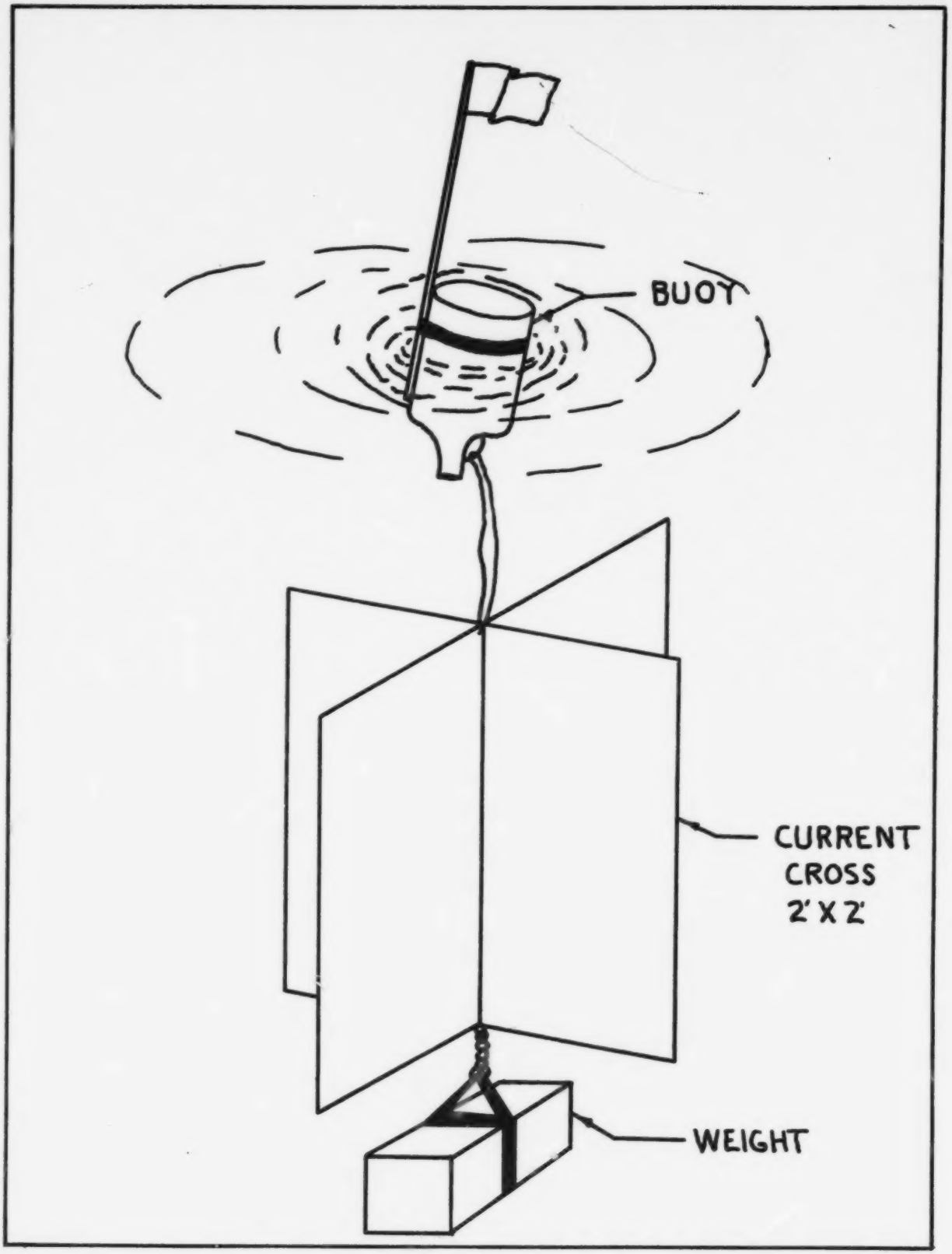


FIG. 14 TYPICAL CURRENT CROSS

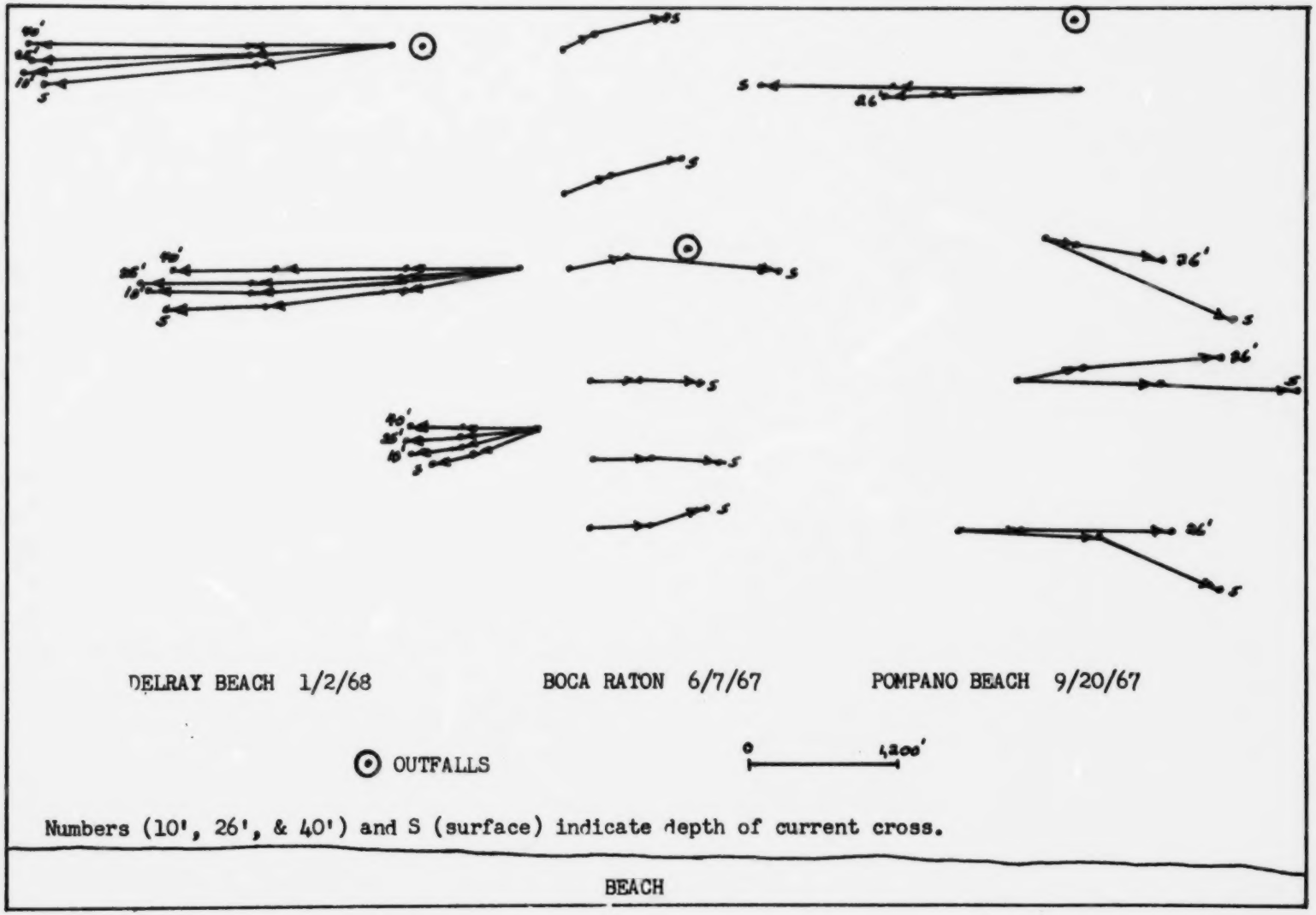


FIG. 15 REPRESENTATIVE CURRENT CROSS PLOTS

2. Dye Marker. As data was developed, it became desirable to try to locate the edge of the north flowing Florida Current (or Gulf Stream) on those days when a south flowing nearshore current was found. It soon became apparent that not only north and south flowing currents were involved but also odd surface motions not amenable to easy study using crosses alone. As a result several runs have been made to determine the dispersal and dilution of the sewage boil, using fluorescein dye as the tracer. In an attempt to obtain the equivalent of an infinite number of current crosses in a row, a line of fluorescein dye was placed in the water running from inside the outfall to well offshore from it. Tracking this line of dye with shore control gave the plots in Figure 16. They suggest the possibility of rotary cells inside the edge of the Gulf Stream. This method of study will be pursued further and for longer periods of time in the second contract year.

The Turner fluorometer, purchased to trace rhodamine dye, has, like many other commerically available marine instruments, needed gross modification for successful use at sea. These changes have been made and it is expected to begin long term tracking of rhodamine marked sewage. Hopefully the track will take us far up the coast before the rhodamine will dilute to the point of undetectability. Our instrument has a threshold of perhaps 1 part in 10 billion and should permit us to say just where tagged sewage, and nutrients released as it is decomposed, will end up.

There is some evidence, in the current cross studies, of an eddy near Delray Beach. Further evidence for this eddy will be sought. If permanent eddies exist, they should be mapped as soon as possible. The evidence for such permanent eddies is weak but the implication for sewage disposal in the ocean are important.

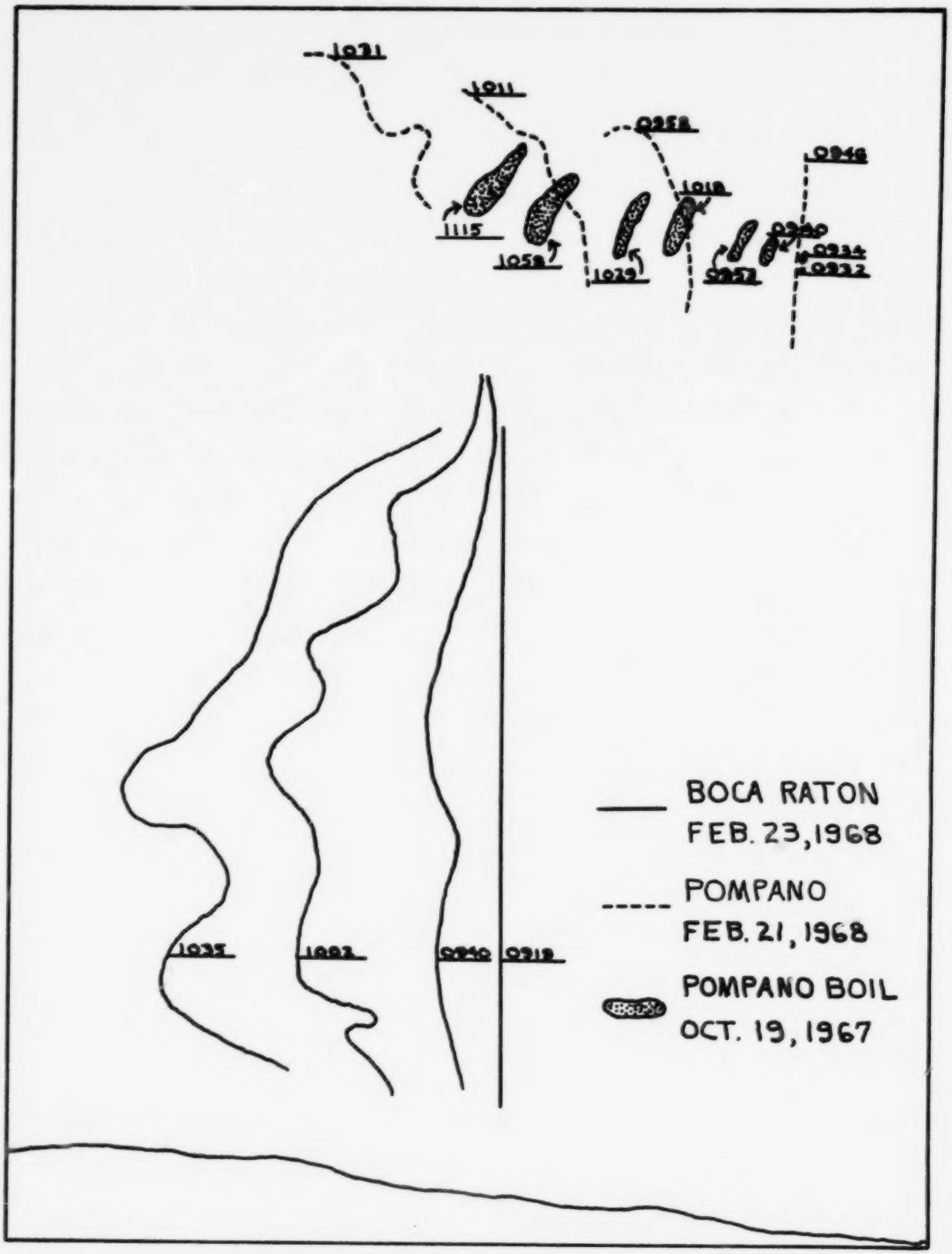


FIG. 16 DYE STUDIES OF CIRCULATION AND DISPERSION

Other Means of Current Study

Preliminary contacts have been made with several groups doing multisensor airborne imaging of the sea. Attempts are being made to cooperate, on a "no additional cost to the project" basis, in a study of the sewage boil and plume by photography with film of various sensitivities, and by infrared scanning to attempt to use the 10° F difference in temperature of the effluent to trace its initial dispersion. The possibilities of such cooperation with Florida Atlantic University and with NASA are excellent.

Much more significant, however, would be success in mapping the current eddies on the shelf by color and temperature differences for they ultimately will determine where the effluent goes as it is reduced by bacteria and time.

Salinities Recordings

Salinities have been determined on a number of samples by conventional techniques. Titration for chloride ion content, with results in parts per million have been made by the Public Health Lab at Lantana. The salinities and chlorinities have been listed in Tables 7, 8, and 9 in parts per thousand, but they are only significant when compared to the oceanographic conditions in the area. The latter include outfall discharge and flow from the inlets. Conversion to salinity is by the following formula: $S°/oo = 0.03 + (1.805\ Cl°/oo)$. Figures 17, 18, and 19 show locations of salinity samples listed in the tables.

Salinities are taken primarily to detect unsuspected variations and thus far no such variations have been found.

Temperature Measurements

All temperature measurements have thus far been made by hand held alcohol and mercury thermometers. These have time constants such that it is inconvenient to make many measurements during a dive. A high speed thermistor temperature recorder will be used during the next phase if a dependable instrument can be

TABLE 7

CHLORIDE & SALINITY

POMPANO BEACH, FLORIDA

Sample Number	Date	Depth	Chloride ‰	Salinity ‰
1	7/24/67	surface	19.170	34.63
2	7/24/67	surface	19.702	35.59
3	10/18/67	surface	19.312	34.88
4	10/18/67	surface	19.312	34.88
5	11/6/67	surface	20.500	37.03
6	11/6/67	surface	20.400	36.85
7	11/6/67	surface	20.200	36.49
8	11/6/67	surface	19.820	35.80
9	10/23/67	surface	20.164	36.42
10	10/23/67	surface	19.753	35.68
11	10/23/67	surface	20.235	36.55
12	10/16/67	surface	21.250	38.38
13	10/16/67	surface	21.000	37.93
14	10/16/67	surface	20.850	37.66
15	10/16/67	surface	20.930	37.80
16	10/16/67	surface	21.050	38.02
17	10/16/67	surface	20.800	37.57
18	11/1/67	surface	19.550	35.31
19	11/1/67	surface	20.200	34.49
20	11/1/67	surface	19.880	35.91
21	11/1/67	surface	19.500	35.22

TABLE 7 (Cont.)

CHLORIDE & SALINITY

POMPANO BEACH, FLORIDA

Sample Number	Date	Depth	Chloride ‰	Salinity ‰
22	11/20/67	surface	20.950	37.84
23	11/20/67	surface	19.500	35.22
24	11/20/67	surface	20.200	36.49
25	11/14/67	surface	19.640	35.48
26	11/14/67	surface	19.850	35.85
27	11/14/67	surface	19.950	36.03
28	11/14/67	surface	19.600	35.40
29	11/28/67	surface	19.600	35.40
30	11/28/67	surface	18.630	33.65
31	11/28/67	surface	19.870	35.89
32	11/28/67	surface	19.500	35.22
33	11/28/67	surface	19.870	35.89
34	11/28/67	surface	19.450	35.13
35	11/28/67	surface	19.250	34.77
36	11/28/67	surface	19.700	35.58
37	11/28/67	surface	19.450	35.13
38	12/29/67	90 feet	2.200	4.00
39	12/29/67	surface	22.500	40.64
40	12/29/67	surface	22.700	41.00

TABLE 8

CHLORIDE & SALINITY

BOCA RATON AND DEERFIELD BEACH, FLORIDA

Sample Number	Date	Depth	Chloride ‰	Salinity ‰
1	11/29/67	surface	20.100	36.31
2	11/29/67	surface	19.900	35.94
3	11/29/67	surface	19.700	35.58
4	11/29/67	surface	19.700	35.58
5	11/29/67	surface	19.990	36.11
6	11/29/67	surface	19.800	35.76
7	11/29/67	surface	19.650	35.49
8	11/29/67	surface	19.700	35.58
9	11/29/67	surface	19.350	34.95
10	10/17/67	surface	19.170	34.63
11	10/17/67	surface	19.830	35.82
12	10/17/67	surface	20.400	36.85
13	10/17/67	surface	19.220	34.72
14	10/17/67	surface	19.650	35.49
15	10/17/67	surface	20.200	36.49
16	10/17/67	surface	19.500	35.22
17	10/17/67	surface	19.870	35.89
18	10/17/67	surface	20.550	37.12
19	10/11/67	surface	20.945	37.83
20	10/11/67	surface	20.945	37.83
21	10/11/67	surface	20.945	37.83
22	10/11/67	surface	21.300	38.47
23	10/11/67	surface	20.945	37.83
24	10/11/67	surface	20.945	37.83

TABLE 8 (Cont.)

CHLORIDE & SALINITY

BOCA RATON AND DEERFIELD BEACH, FLORIDA

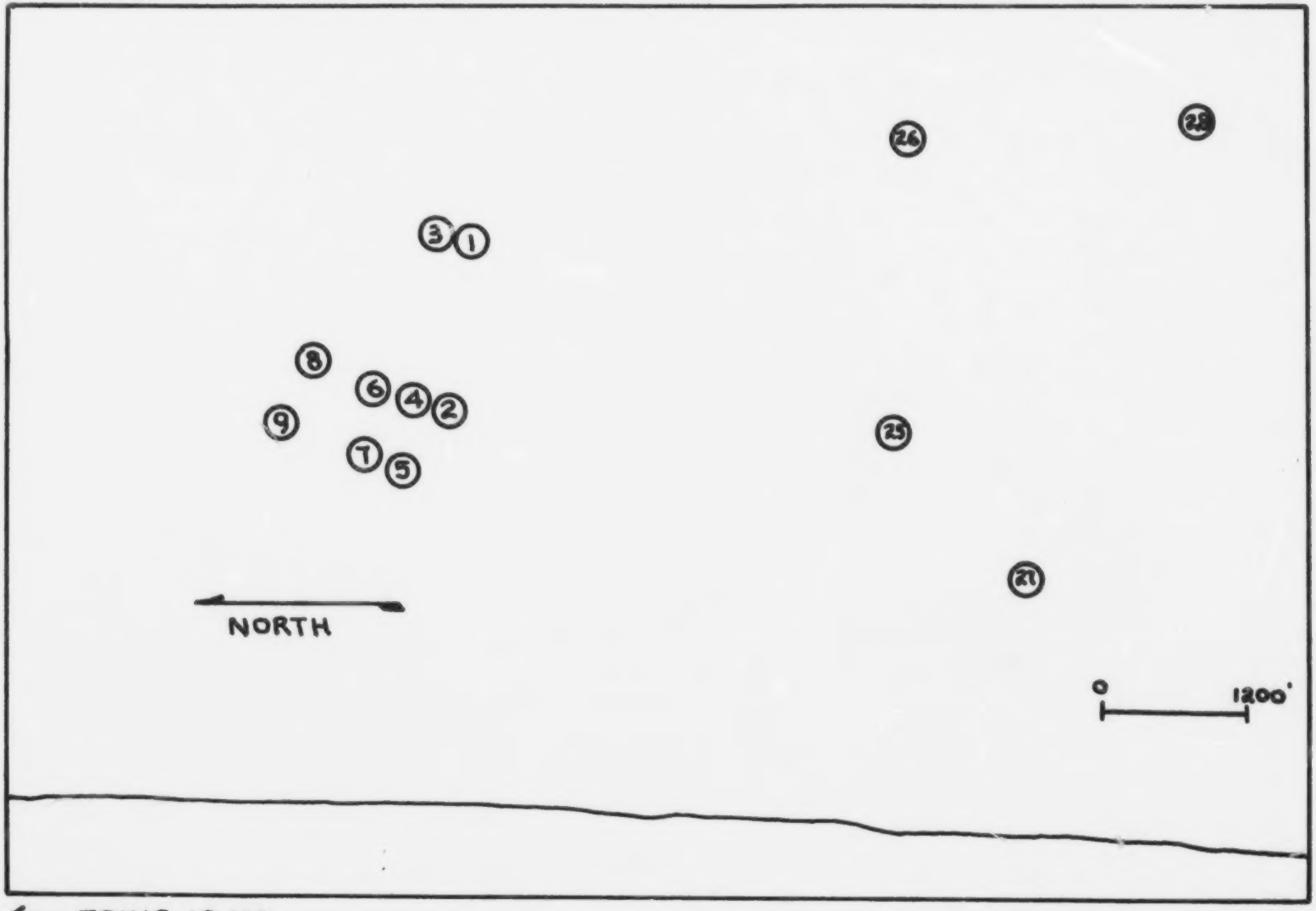
Sample Number	Date	Depth	Chloride ‰	Salinity ‰
25	7/10/67	surface	22.365	40.39
26	7/10/67	surface	20.945	37.83
27	7/10/67	surface	19.348	34.95
28	7/10/67	surface	19.525	35.27
29	10/11/67	surface	21.300	38.47
30	7/12/67	surface	20.058	36.23
31	7/12/67	surface	20.590	37.19
32	1/22/68	55 feet	21.800	39.38
33	1/22/68	surface	21.500	38.34

TABLE 9

CHLORIDE & SALINITY

DELRAY BEACH, FLORIDA

Sample Number	Date	Depth	Chloride ‰	Salinity ‰
1	11/27/67	surface	20.220	36.52
2	11/27/67	surface	19.180	34.64
3	11/27/67	surface	19.480	35.19
4	11/27/67	surface	18.850	34.05
5	11/27/67	surface	19.660	35.51
6	11/27/67	surface	19.800	35.76
7	11/27/67	surface	19.480	35.19
8	11/27/67	surface	19.850	35.85
9	11/27/67	surface	19.480	35.19
10	11/27/67	surface	19.050	34.41
11	1/2/68	92 feet	12.400	24.41
12	1/2/68	40 feet	20.100	36.31
13	1/2/68	surface	20.900	37.75



← JOINS 18 NO.

FIG. 18 SOUTH SALINITIES - DEERFIELD BEACH AREA

20 R

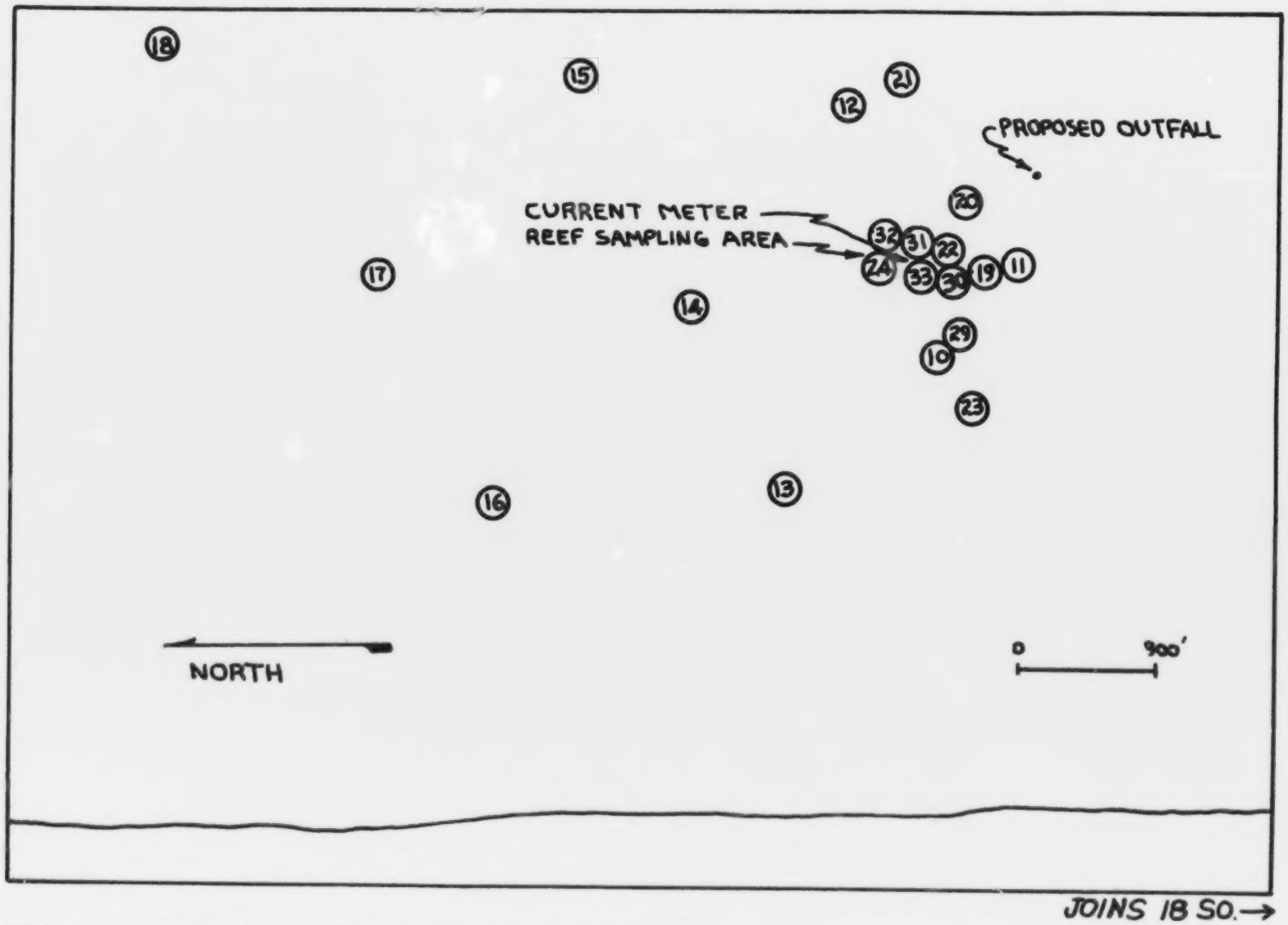


FIG. 18 NORTH SALINITIES- BOCA RATON AREA

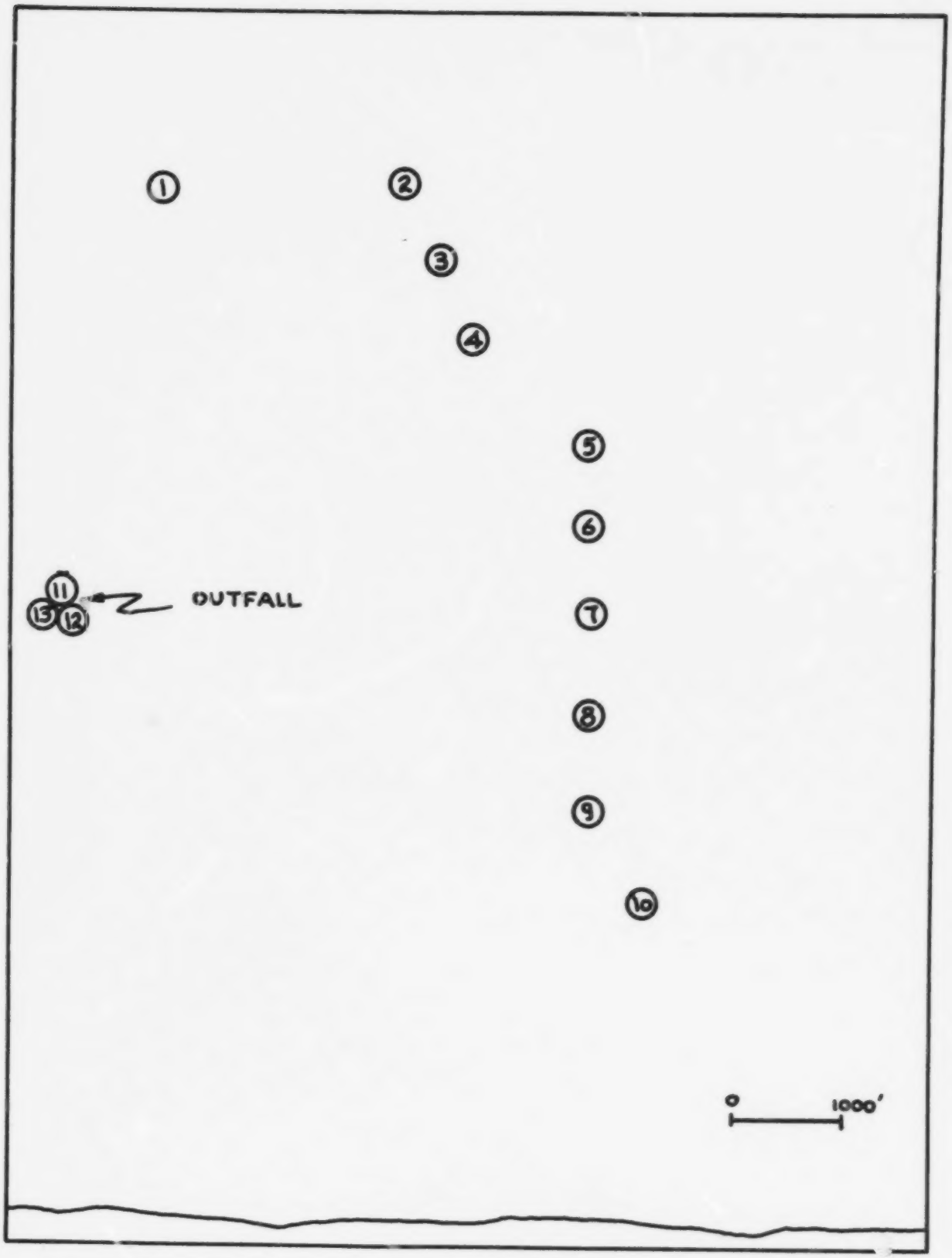


FIG. 19 SALINITIES- DELRAY BEACH AREA

located or built. It is hoped to record one or more thermistors on one of the current meter towers as well.

Visibility Measurements

At essentially every current cross station a Secchi disk reading is taken. The Secchi disk is a weighted 10 inch white disk lowered until it disappears from view. Most conventional Secchi disk readings suffer from the effects of surface reflection. When we cannot see the disk as it touches bottom, or at the end of its 100 foot long tether, a "look box" or surface reflection eliminating device is used to obtain a true depth of extinction for the Secchi disk.

It should be possible by the time of beginning of operation to make general statements about any decrements in visibility caused by the Boca Raton outfall but because of extreme variability of visibility, predicting it is a full project in itself, unless it happens to fall out of our study of the currents in the area, which is quite possible.

Visibility ranges from a few feet to substantially more than 100 feet in the project area. Very good visibility indicates sterile, non-fertile Gulf Stream water intruding far up onto the shelf. It is, in itself, a useful indicator of the inner edge of Gulf Stream derived water, if not, in fact, the edge of the north flowing Gulf Stream itself.

Meteorological Measurements

The U. S. Coast Guard Station at Hillsboro Inlet records wind speed and direction and barometric pressure. These records are made available to us on a regular basis and will be correlated, if possible, with current speed and direction. The main probability of sewage contamination of any beach area appears to be from wind blown surface floating particles. Communition so shreds solid material that the turbulence of the water normally

keeps it dispersed through a thick surface layer and the probability seems rather small. Nevertheless, it will be further investigated.

DISCUSSION

After a slow start, occasioned by receipt of our first installment of operating funds a month and a half late the first year was spent collecting the basic data discussed above and seeking those areas of greatest possible value to the project, in demonstrating the limitations and effects of waste disposal on an ocean shelf, for more intense study. Phase I of the three year study was to include sampling of the marine fauna and flora for a year before the Boca Raton outfall began discharge of sewage. While the proposal was being evaluated, a suit was brought to stop construction of the outfall on some legal technicalities regarding the validity of the outfall bond issue. The matter has been resolved in favor of the city of Boca Raton and the outfall will be constructed this summer. The additional time before discharge will enable us to complete our sampling. The proposed Phase II operations, including the study of the ecological effects of effluent on the micro and macrobiota of the outfall area, using Phase I data as the baseline, will hopefully begin before the end of Year II, if no further delays are experienced in construction of the outfall system.

Current studies are vital to intelligent planning and approval of any ocean outfall. The initial results of our studies indicate that, as expected, currents must move predominantly north or south parallel to the coast of Florida. A persistent deviation from this pattern would result in a significant change of sea level along shore if the water flowed either onshore or offshore. Nevertheless, the speed and direction and nature of the flow is important to any study of dispersal of pollutants. Indication of this is the remarkable

scarcity of boil observations when currents are over 1/2 to 3/4 of a knot (nautical mile per hour). Eddies, which appear to be shed between the Gulf Stream and the beach, may account for the abrupt reversals and swings in current direction often recorded by both the drift measurements and the recording current meters. Otherwise one must postulate sloshing of the water on the Southeast Florida continental shelf, first north, then south. This is difficult to justify since there is extreme variability in period of the direction changes, requiring similar variability in the forcing phenomena. In summer currents are generally more rapid than in winter, too, and persist in one direction for relatively long periods of time, Figure 12.

Meanwhile, the limitations of commercial current meters was brought home forcibly to us, Figure 20. Whereas I had previously had my current meters constructed to my order, in the absence of a well equipped shop and men to man it, we went to the oceanographic instrumentation industry. The meters used suffered severly from dissimilar metals corrosion and from bearing failure. Dr. Fred Alt, of the U. S. Navy Oceanographic Office, tells us that our experience is standard. It has, however, seriously limited our current speed recording.

As our ecological study advances, we find that a good deal of aid can be obtained from the Smithsonian Institution in narcotizing, fixing and preserving marine specimens. These will be used for comparison with creatures collected after the outfall is in operation. Mr. Adair Fehlmann, Curator of the Smithsonian Sorting Center, has offered to help us with both preservation and identification. While the latter is not one of our immediate project objectives, it is quite desirable.

Methods of collecting the fauna of the sand bottom, particularly those forms living under the sand, are not well developed. A technique developed by Dr. McAllister for treasure hunting underwater is being adapted for under-sand collection of organisms.

From time to time we have been called upon to brief local authorities on the use of ocean outfalls. Among such groups have been the Federal Water Quality Control Agency; the State of Florida Board of Health; the Palm Beach County Legislative Delegation, Committee on Air and Water Pollution; the City Manager and City Council of Boca Raton; and members of the Pompano Beach City Engineers Staff. Great care has been taken to avoid publicising the project in terms of ocean outfalls, pollution. and sewage discharge. It has been the policy of Florida Atlantic Ocean Sciences Institute to let this report and any terminal reports speak for the project.

The members of the project staff and particularly the principal investigator make their living in the ocean and recreate there almost exclusively. They have a strong vested interest in seeing to it that an unreasonable level of pollution does not exist. It is hard to imagine an oceanographer who would deliberately allow pollution of HIS ocean. This can, perhaps, be kept in mind by the various readers of this report.

RESULTS

Studies of the current regime on the Southeast Coast of Florida are well underway using multiple approaches. The major conclusions thus far are:

a. Currents normally trend parallel to the Florida Coast, flowing both north and south in quasi-cyclic fashion. At times the flow at two points along the coast, within the project area, is toward each other. At

other times both flow in the same direction but at different speeds. Sometimes reversals of direction of flow occur in periods of about ten minutes. Sometimes surface flows and bottom flows are in different directions, and on rare occasions they are almost diametrically opposed. There are periods of almost no currents and times when near shore water speeds may reach more than two knots. The summer currents tend to be faster and to persist in one direction for much longer periods of time. In the winter eddies, or rotational water motion, are the rule, with much shorter times of north or south flow. No apparent correlation with tidal effects or wind has been found. The reasons for the erratic and unpredictable current picture on the shelf may emerge during the next year of the project but are presently obscure. Computer techniques will be applied to the current analysis in the second year.

Some provocative suggestions can be made. Suppose the Gulf Stream sheds eddies along its western margin. Would these not rotate while moving generally northward? Could they hold effluent for a longer time on the shelf, while, mixing it with a greater volume of water, perhaps result in considerably better dispersion than if straight upcoast motion only was involved? If there are permanent eddies at some locations, should outfalls be located to discharge into the offshore flowing limb of the eddy to give the greatest possible dispersion of sewage?

The evidence for such eddies is by no means conclusive and the questions raised are only speculations at present. Perhaps in the next year we can begin to pin some of them down.

b. The macro and micro organisms of the contract area have been and continue to be sampled. There have proved to be seasonal cycles in the

distribution and abundance of some organisms. Others have been discovered which were previously unknown in this area, and among the microorganisms a number of new species have been found. Few forms indicative of eutrophication or straightforward fecal pollution have been found either in the water or on the bottom, except for the coliform bacteria in the boil and down plume for relatively short distances. By the time discharge begins from the Boca Raton outfall, sometime this year, the area will have been moderately well sampled, in the water, and under the bottom and on both sand flats and reef, both quantitatively and qualitiatively. Only the vertebrates will be neglected and underwater photographic identification of the fish, at least, will have been started.

Photo coverage of the reef is underway and will be complete enough to permit return to specific sites, when the outfall is operating, for follow up photos to supplement the follow up sampling.

The reef fauna and flora are rich and varied with a number of hitherto unsuspected forms. Some corals have been discovered well north of their previous range limits. Crinoids abound in the area but withdraw into the reef (or die and disappear?) as colder weather comes. The water is impoverished as befits water derived largely from the sterile Gulf Stream, although it is, by comparison, much richer than the Gulf Stream. The sediment water interface has an equally sparce biota, not indicative of pollution. Since this impoverishment occurs near existing outfalls as well as at Boca Raton, it is not expected that any major difference will be detected after effluent discharge. This is, of course, in contradistinction to a number of fishermens reports which state that the reef near outfalls is dead. Figure 21, taken immediately beneath the Pompano Beach outfall

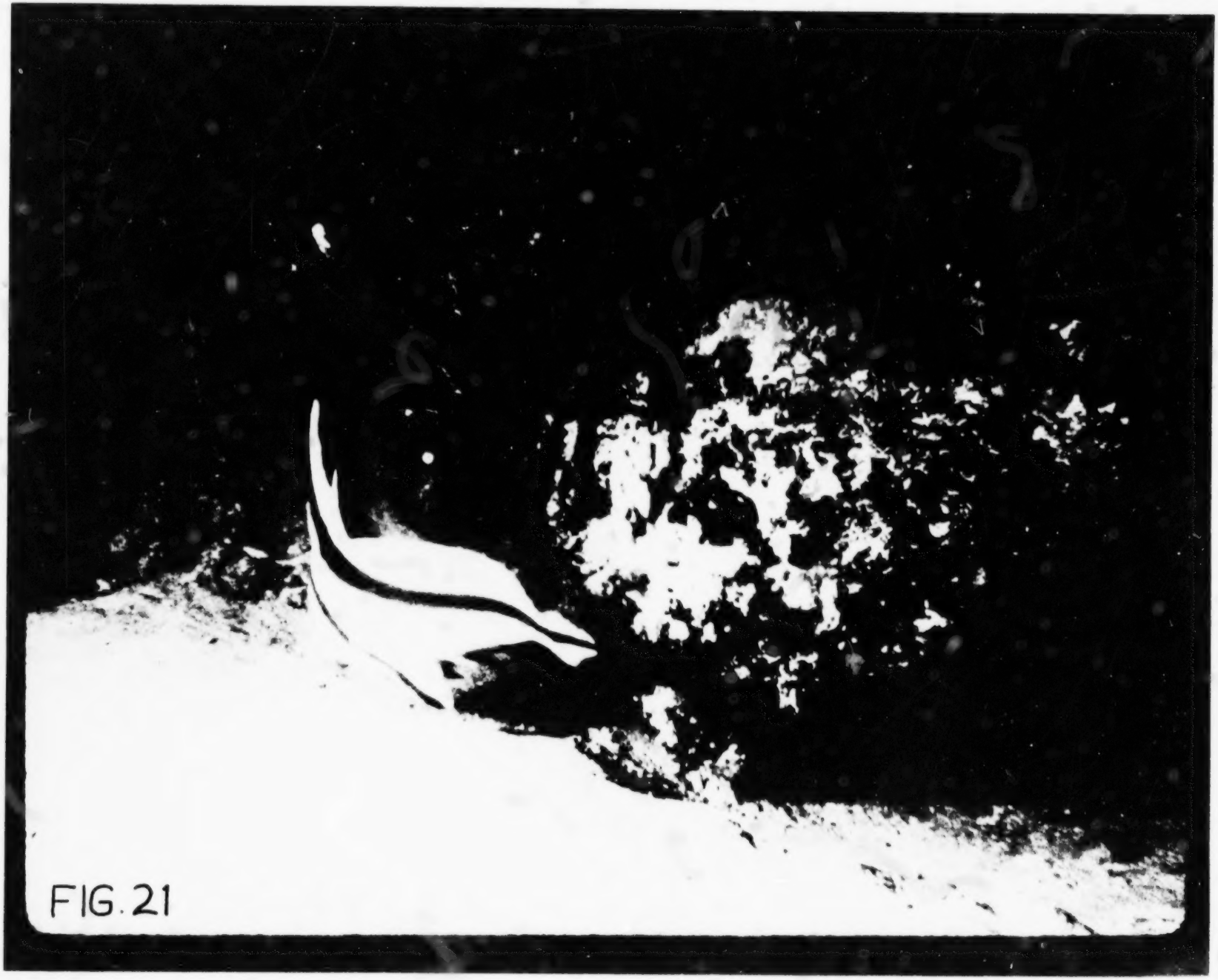


FIG. 21

shows nothing but clean sand and vigorous reef growth, comparable to that on any reef of similar depth in the area.

Viruses may prove longer lived than coliform bacteria in sea water. Experiments to test the hypothesis that viruses, both cultured and "wild", could be used as indicators of pollution are underway. The first steps, now that T-2 phage has been shown to be viable in sewage and in sea water, is to use this virus to determine distribution of sewage effluent in sea water. Ultimately, the study will lead to evaluation of the role of wild animal viruses as pollution indicators and to see how far from the source they persist in sea water.

c. Toward the end of this contract year, more emphasis was placed upon methods of monitoring fertility of the sea water. Determinations of NO_3^- and B.O.D.'s have been made. The few samples thus far taken suggest, like many other lines of evidence listed above, that pollution of the shelf is not yet a problem except immediately over the outfall.

d. Dr. Lackey finds cellulose fibers in his plankton samples and suggests that cellulose particles, possibly traceable to toilet paper, may be good pollution indicators, longer lasting than any living form. This line of research will be pursued further.

APPENDIX A

Virus Studies

Dr. Glenn Waddell

Introduction

Viruses are unique biological entities, since outside the Living cell they are inert particles, consisting of a nucleic acid core surrounded by a coat of protein. Because of these unique properties it is proposed that viruses would represent a more satisfactory measure, or indicator, of pollution than the normally employed Escherichia coli.

Virus studies have, then, been included in this study of dispersion and pollution of the ocean environment. These investigations have been underway for approximately 6 months (since Nov. 1, 1967).

Our research has centered thus far on the basic information required in order to begin studies directly in the marine environment. The bacterial virus, bacteriophage F2, has been chosen as the indicator virus for the determination of pollution by the ocean outfall system. Attempts have been made to determine the dieout of the virus in the marine environment. We have attempted, to study the die-out, or decay, of this virus under as natural conditions as could be duplicated in the laboratory.

The bacteriophage F2 was obtained from Dr. Hsu at Johns Hopkins University. This virus is a small icosahedral virus infecting only the male strains of E. coli K-12. This property is of considerable importance in laboratory studies simulating natural fresh water sewage treatment environments as well as the environment of an ocean outfall boil. The results are delineated in the following section.

Experimental Results

In order to determine if a background contamination by bacteriophage F2 existed in the settling pond at Boca Raton sewage treatment plant or in

the Pompano Beach ocean outfall boil of untreated comminuted wastes, repetitive attempts at isolation were undertaken. All attempts indicated that phage F2 was not present, or could not be detected, in either of these environments. Moreover, it was found that the normal phages found in the human wastes would not infect our strain of E. coli K-12, and that bacteriophage F2 would not infect the normally found E. coli in human wastes. These experiments indicated the efficacy of employing this unique phage as an indicator organism for our further studies.

Experiments have been conducted to determine the die-out, or inactivation, of the F2 phage under conditions designed to simulate the natural environments under which future testing will be conducted.. Samples of water obtained from the settling pond at the Boca Raton sewage treatment plant inoculated with F2 phage at a concentration of 1×10^7 pfu/ml (plaque forming units per milliliter) resulted in a slow inactivation of only 2 logs of virus in a period of 6 days. Similar experiments conducted with the same initial sample filtered through a 0.22 micron filter to remove macromolecular constituents (proteins, carbohydrates and other organic particles) resulted in a decrease of 4 logs of virus in a similar 6 day period. Thus, removal of the organic particulate matter from sewage waters results in an increased die-out of the indicator phage. Virologists have found that increased protein levels with some virus preparations have a stabilizing effect, particulary in regard to animal viruses. This finding is of major importance, for viruses in human wastes, when in the presence of high organic particulate matter, may survive for long periods of time. These results are depicted in Table 10. Similar experiments conducted with sea water samples obtained from the Pompano Beach ocean outfall boil revealed a loss of 1 log of virus the first day and a total loss of 4 logs over a 6 day period. In order to maintain conditions as natural as possible, no filtration was employed in these early experiments.

Table 10 -- Duration of F2 Survival in Fresh Sewage Water.

Water	Log 10 of Surviving F2						
	1 day	2 days	3 days	4 days	5 days	6 days	7 days
Fresh Sewage Water-Unfiltered	6.8	6.7	6.5	6.0	5.3	5.0	4.0
Fresh Sewage Water-Filtered (.22 μ)	6.5	5.2	5.0	4.2	3.0	2.3	0

The log 10 values for the above samples are based on 3 or more repetitive samples of each individual sample.

Table 11 — Duration of F 2 Survival Using Dialysis Bags

Water	Log 10 of Surviving F2						
	1 day	2 days	3 days	4 days	5 days	6 days	7 days
Distilled Water	6.1	5.5	5.5	5.5	5.0	4.5	4.5
Sea Water Untreated	4.0	3.1	2.5	2.0	0	0	0

The log 10 values for the above samples are based on 3 or more repetitive samples of each individual sample.

Virus suspensions in dialysis bags have been employed for the study of inactivation of animal viruses in different environments (Berg. G., editor, Transmission of Viruses by the Water Route, (1967), John Wiley & Sons, Inc.). Preparations of F2 phage containing 6.2 logs of virus were suspended in water obtained from the boil of the sewage outfall system, and similar bags were suspended in distilled water as a control. The results of such an experiment are shown in Figure 22 and Table II. Results of repetitive experiments have indicated a marked rate of die-out in the dialysis bags suspended in the waters from the outfall boil. Results of different experiments have shown a total die-out of the F2 phage in 4 to 5 days. This would indicate the inactivation of this phage by ionic constituents found in sea water, for macromolecular particles are kept out of the dialysis bags under these conditions. This did not, in our opinion, represent a natural environment so our attentions were turned elsewhere.

Attempts to demonstrate initial effects of osmotic shock upon the F2 phage indicated that when samples are removed immediately after addition of small volumes of phage to the waters obtained from the outfall boil there is no loss in the infectivity of the virus preparation. If osmotic shock has occurred one would expect an immediate dimunition in titer of the virus.

Further experimental evidence on the effects of macromolecular constituents as well as differences of volume are shown in Figures 23 & 24 and Tables 12 & 13. Survivors of phage F2 when assayed daily during exposure to samples of outfall boil sea water, and treated by filtration and autoclaving, again pointed out the protective effect of the macromolecular constituents in the waters containing comminuted human wastes. It was apparent that autoclaving the sea water samples had no marked effect on the longevity of the F2 phage. There was no marked effect of volume (100 ml as compared to 10 ml) on survival of F2 phage. The increased survival in the 100 ml samples was assumed due to the higher level of virus present at the initiation of the experiment (8.2 logs for the

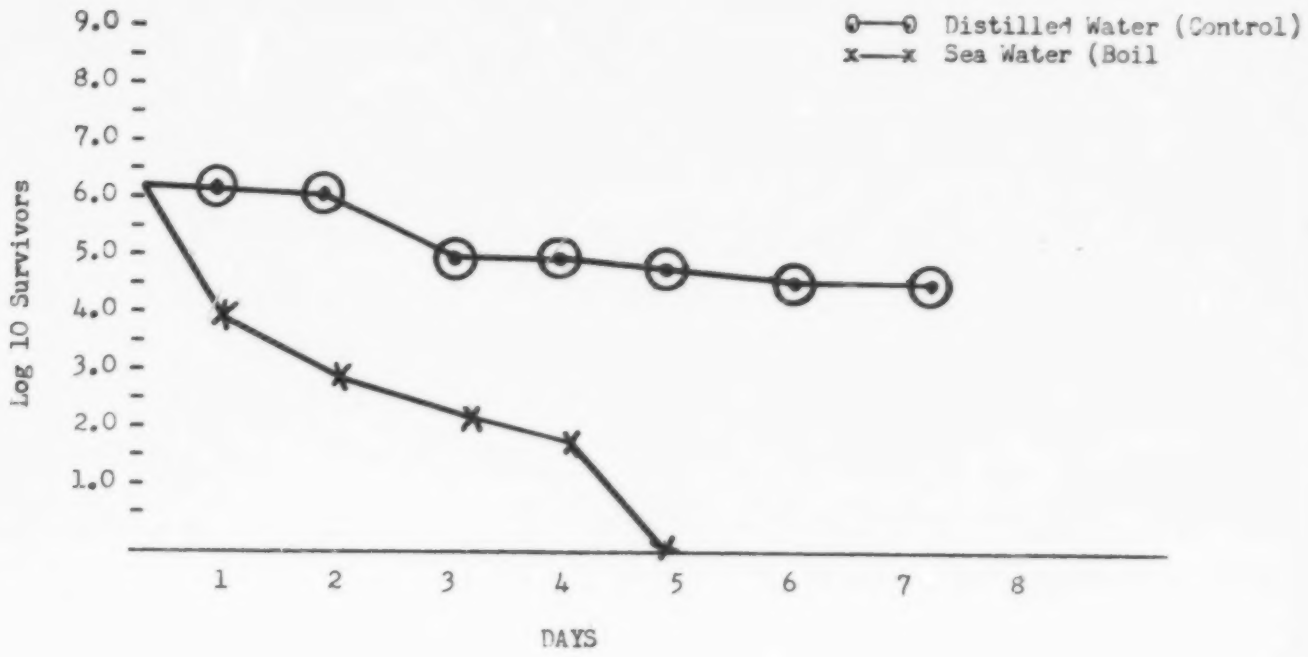


Figure 22 Bacteriophage F2 survival in dialysis bags suspended in distilled water (O—O) and sea water obtained from ocean outfall boil (x—x). Each point represents three or more duplicate samples.

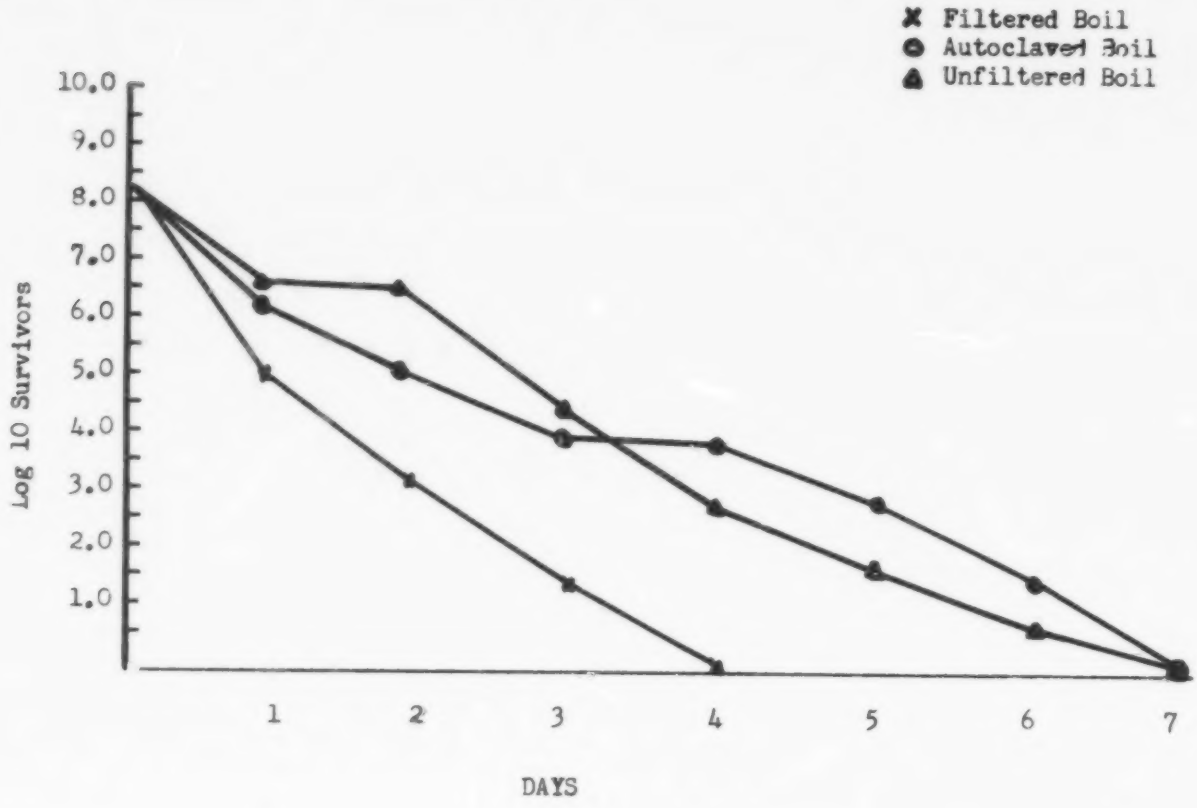


Figure 23 Bacteriophage F2 survival in 10.0 ml samples of ocean outfall boil water treated by filtration (x—x), Autoclaving (0—0) and not treated. Each point represents three or more duplicate samples.

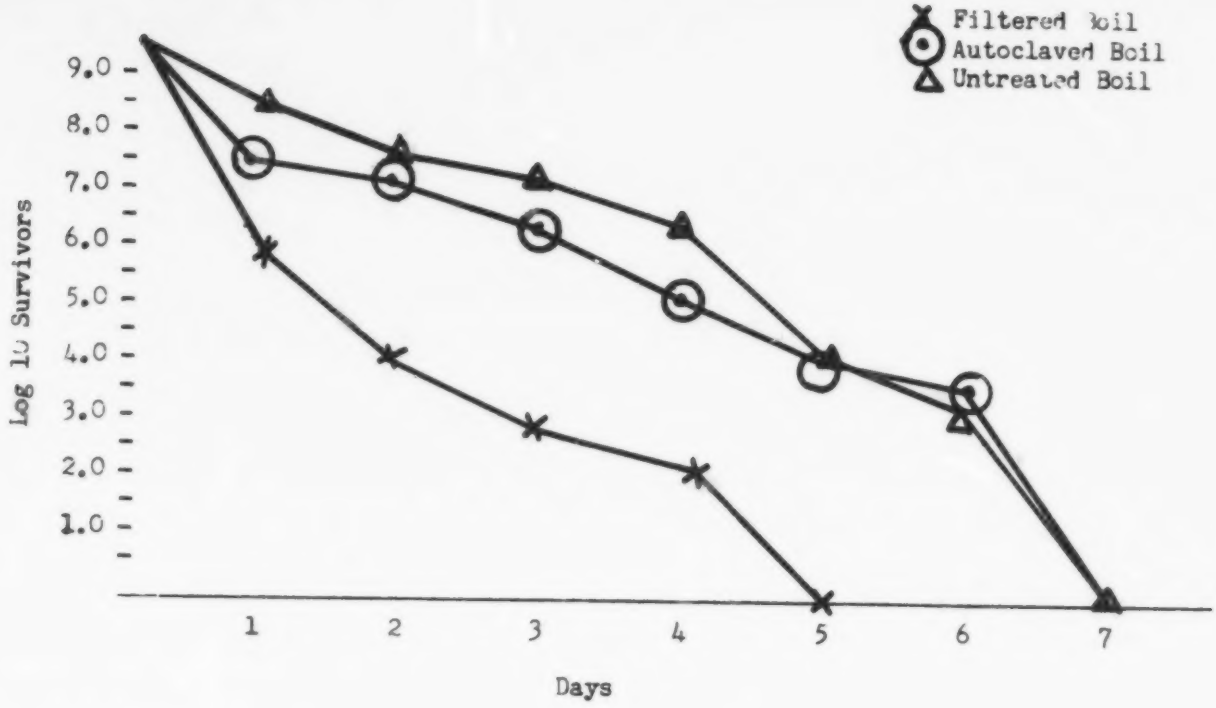


Figure 24 Bacteriophage F 2 survival in 100.0 ml samples of ocean outfall boil treated by filtration (x—x), autoclaving (o—o), and not treated. Each point represents three or more duplicate samples.

Table 12 — Duration of F2 Survival in 10 ml. Samples

Water	Log 10 of Surviving F 2						
	1 day	2 days	3 days	4 days	5 days	6 days	7 days
Marine Sewage Water Untreated	6.7	6.5	4.5	3.2	1.8	1.3	0
Marine Sewage Water Autoclaved	6.2	5.1	4.2	4.1	3.2	1.7	0
Marine Sewage Water Filtered (10 mu)	5.1	3.2	1.5	0	0	0	0

Table 13 — Duration of F2 Survival in 100 ml. Samples

Water	Log 10 of Surviving F 2						
	1 day	2 days	3 days	4 days	5 days	6 days	7 days
Marine Sewage Water-Untreated	8.3	7.5	6.8	6.2	4.3	3.1	0
Marine Sewage Water-Autoclaved	7.6	7.0	6.3	5.0	4.0	3.4	0
Marine Sewage Water-Filtered (10 mu)	6 .1	4.1	2.8	2.2	0	0	0

The log 10 values for each of the above samples in both tables are based on the results obtained from 3 or more repetitive samples of each individual sample.

10 ml samples, 9.5 logs for the 100 ml samples).

Rhodamine dye is being used to trace the sewage effluent for current studies. It is highly desirable to use dyed water as an indicator of the core of effluent in the plume down current from the outfall. To determine if it would have a toxic effect, phage F2 was suspended in concentrations of the dye ranging from 1 part per 1000 to 1 part per 100,000, in order to determine the deliterions effects, if any, on this virus. There were no differences from the controls in either of the concentrations over this range except for slight indications of increased longevity, a protective effect, in the higher concentrations. Thus, it is our belief that rhodamine dye will greatly facilitate recovery of the F2 phage from the ocean once seeded into the outfall system. This dye will not only present a direct visual means of determining sampling areas, but can also be detected in concentration of less than one part per billion by a project fluorometer.

Summary and Conclusions

The work accomplished thus far has established the effects of the marine environment, particular reference to the outfall system, upon the bacteriophage F2. The unique properties of this phage makes it a useful tool, or indicator, for the study of sewage polution in the ocean. The failure to show a background of this phage under natural conditions permits studies of dispersion and polution when seeded into the ocean outfall system. The failure of normal bacteriophage flora to multiply on our strain of E. coli K-12 lends support to this tenet.

It is clear that the macromolecular, or organic, constituents present in comminuted human wastes have a protective effect on the F2 virus. This effect, which has been suspected with other viruses as well, is of major

importance in studies of polution, for viral agents may remain in the "viable" state for long periods of time allowing for possible contamination of recreational areas by currents or other environmental factors.

It is anticipated that seeding studies of the ocean outfall systems will be initiated shortly after this report is written. Initial experiments will be attempted using rhodamine dye as a visual indicator of sampling sites as well as an indicator of dispersion of the seeded sample. This is possible because of the lack of toxic effects on the F2 phage as shown by our laboratory studies.

APPENDIX B

REEF SAMPLING PROGRAM

Terry Davis

INTRODUCTION

This portion of the biological sampling program concerns the macrofauna and flora of the coral reef. The coral reef is an excellent area to study since it does not change drastically in short periods of time except under extreme conditions. A coral reef at a depth of approximately 60 feet represents a fairly stable environment affected mainly by water temperature, salinity changes, and water turbidity. Although these factors change almost constantly, over a period of years a fauna and flora has been established which can withstand these variations. The addition of another factor, either beneficial or detrimental, will produce noticeable changes.

PURPOSE

The purpose of the reef sampling program is to determine quantitatively the macrofauna and flora of a reef in close proximity to a future location of an ocean outfall system. This will serve as a basis for comparison for the sampling program which will be carried out after the ocean outfall is put into operation.

REEF DESCRIPTION

A total of seventeen stations were laid out by the principal investigator on a general East-West line across the reef off Boca Raton in approximately 60 feet of water. The location of this reef sampling area and its distances from shore and the future sewage outfall is shown in figure 10 . A profile of the reef and the location of the stations is shown in figures 6 and 5 respectively. Each station was marked with two concrete blocks and is approximately 2 feet square.

SAMPLING METHODS

Collection

Since the coral reef is composed of hard, calcareous rock, it does not lend itself to methods usually employed in obtained benthic infauna, epifauna, and flora, including the various mechanical grabs, (orange peel, etc.), rock dredges, or trawls. The reef is located in approximately 60 feet of water and is therefore readily accessible, however, by divers equipped with SCUBA gear figure 3 . Divers, working in teams, using hammers and chisels, were employed to remove the coral rock, place it in buckets, and bring it to the boat with the aid of a lifting bag. The buckets containing the coral rock and saltwater were delivered to the land based laboratory within one or two hours from time of collection, and sometimes sooner.

Laboratory Treatment of Coral Rock

Coral rock does not lend itself to methods used for obtaining specimens from other types of bottom materials such as mud, sand, etc. It cannot be screened, washed, etc. The epifauna and flora were removed as best as possible from the surface of the rock with forceps, scapel and by hand. The live corals were measured for an approximate surface area and all rock was then broken into pieces measuring from 1 to 1½ cubic inches. As the rock was broken, the infauna was removed and placed in jars containing saltwater. Separate jars were used for each phylum from each individual sample area.

Preservation

After all the specimens had been removed from the broken rock they were perserved in either 70 per cent etnyl alchol or 3 per cent formalin depending upon the type of organism. Each jar was labeled with the following information:

General Area _____

Environmental Type _____

Station _____

Approximate Depth _____ Date _____

Phylum _____

Class _____

Remarks _____

All specimens were stored at the laboratory.

DISCUSSION

Reef in General

The reef lies in approximately 60 feet of water and is not affected by wave action as a reef close to shore would be. Since there is little or no change in the environment of the reef from one side to the other, the reef shows very little zonation, such as reef front, reef flat, etc., and may be classified as a homogeneous reef. The reef consists mostly of coral rock covered with algae. Scattered almost evenly upon this dead coral foundation are live hard corals - hermatypic zoantharians, soft corals (alcyonarians) and sponges. There are no distinct zones of hard or soft corals or sponges.

Each sampling station was chosen by the principal investigator to represent a slightly different sub-environment on the coral reef, and to sample the fauna and flora from one side of the reef to the other. The following are short discussions of each sampling station:

Station A - 61 feet - samples 22 August, 1967.

Station A is located on the inside or shoreward edge of the reef and represents the coral - sand environment.

Station B - 57 feet - sampled 22 and 25 August, 1967.
Station B represents the coral environment with no sand and is close to the inside edge of the reef.

Station C - 55 feet - sampled 25 August, 1967.
Station C is at the foot of an escarpment and a slight sand silt contend was found among the dead coral. Live corals were also present.

Station D - 50 feet - samples 6 September, 1967.
Station D is located at the top of the escarpment and represents a coral sub environment. A high quantity of green algae was noted when compared to the three previous stations.

Station E - 53 feet - sampled 14 September, 1967.
Station E was staked out on the top of the reef and some silt was found among the coral. Some sand is present on the top of the reef, but for the most part it is coral rock.

Station F - 54 feet - sampled 26 September, 1967.
Station F is also located on top of the reef and represents an environment similar to that present at Station E.

Station G - 56 feet - sampled 26 October, 1967.
Station G also is a representative of the top of the reef and is generally comparable to Stations E and F.

Station H - 61 feet - sampled 1 November, 1967.
Station H is on the top of the reef also. However it represents a significantly different habitat. It is located in a depression in the reef which has partially filled with coarse sand (shell fragments, etc.) and is surrounded by coral rock. Small, loose pieces of dead coral were found in the sand and some of the rock below the sand was removed, as well as some from the surrounding "wall". Most specimens collected were found in the rock. Live

coral was found adjacent to the pocket of sand.

Station I - 62 feet - sampled 7 November, 1967.

Station I is located in an area characterized by alcyonarians but none were found in the 2' x 2' area sampled which seems to represent a sub type.

Station J - 58 feet - sampled 18 December, 1967.

Station J is also in an area dominated by alcyonarians, however madreporian (hard) corals were almost as prominant. It is representative of the alcyovarian environment.

Station K - 58 feet - sampled 8 December, 1967.

Station K, like Stations I and J, is in an alcyonarian area, but with less madreporarians present than in the immediate vicinity of the other two stations.

Station L - 60 feet - sampled 15 November, 1967.

Station L may be described as a typical reef area with both alcyonarians and madreporarians present, different from previous environments.

Station M - 58 feet - sampled 27 October, 1967.

Station M lies in an area of heavy concentration of alcyonarians and a considerable sponge fauna. This is not to say that there is a correlation between the two.

Station N - 63 feet - sampled 16 February, 1968.

Station N is at the top of the seaward slope of the reef which leads to the silty sand at the bottom. It is an area of median sponge, madreporarian and alyconaria population. There is considerable silt content.

Station O - 73 feet - sampled 22 February, 1968.

Station O is further down the slope and has increased silt content, over station N. This area, like station N, is not dominated by any one type of epifauna.

Stations P - 76 feet - and - Q - 80 feet - will be sampled in the near future.

Station Fauna and Flora

The following table is a quantitative representation of the major fauna phyla found in the reef samples. A high reading for any one phylum at any one station does not necessarily mean that the area is dominated by the members of that phylum, nor does the absence of a phylum in the table indicate that it is not represented in the immediate vicinity. A more complete list of phyla will be submitted at a later date. As started before, this reef has proved to be nearly homogeneous and most quantitative variances are due to a slightly larger quantity of material being examined.

PORIFERA

The sponge population may be classed as both infauna and epifauna as some of the sponges were found to penetrate down into the coral rock. There was a good percentage (30-40%) of low, encrusting type sponges as compared to sponges attached to the rock by a basal portion. The quantity of sponge collected was determined by liquid displacement. The sponge was removed from the preservative and placed in a water filled container with a spout near the top, which overflowed into a graduated cylinder. The quantity of fluid displaced was then measured and taken to represent the volume of the sponge. While volume may not be the best measure, there are problems associated with counts of individuals and with gravimetric measures, as well.

TABLE 14

Phyla	Unit of Measure	Station														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Porifera	cm^3	1560	880	380	700	160	470	600	120	1420	440	200	200	3180	1880	750
Cnidaria Fam. Madreporaria	cm^2	50	170	484	48	0	103	476	78	815	42	0	429	742	0	0
S. Cl. Alcyonaria	cm^3	0	90	0	0	9	27	24	10	0	35	68	25	780	53	0
Sipunculida	ea.	6	15	12	11	7	0	2	5	2	7	1	1	5	9	5
Annelida	ea.	17	16	10	20	5	19	6	4	4	11	21	5	1	10	6
	cm^3	7	9	3	18	3	12	6	15	8	6	6	4	2	7	3
Mollusca	ea.	16	16	15	26	8	16	5	8	6	11	8	7	10	11	6
Arthropods	ea.	16	20	5	20	6	30	16	5	18	24	21	27	43	24	9
Echinodermata	ea.	8	13	6	12	10	16	22	1	4	6	4	6	31	20	4
Algae	cm^3	100	35	0	6	56	57	25	33	50	65	100	20	35	28	80

CNIDARIA

Class Anthozoa
Subclass Zoantharia
Order Madreporaria

The madreporarians or reef corals (hard corals) range in size from less than an inch to 1 or 2 feet in diameter and are scattered over the reef, covering approximately 20-25% of the reef area. A total of 17 species were collected, and a representative specimen of each was retained. The calcium carbonate skeleton was washed free of animal tissue with high pressure water and was then placed in 2.5% chlorine bleach solution for several days to remove any remaining animal matter. Those specimens not retained for the permanent collection were identified and measured for a quantitative representation.

Subclass Alcyonaria

The alcyonarians, or soft corals, were preserved in formaldehyde solution and quantitatively measured by the same method as the porifera. The alcyonarians are scattered over the reef almost evenly but there are areas where the concentration is slightly greater.

ANNELIDA

The annelids were represented almost entirely by polychaetes and all but one specimen were infauna. They were found in their burrows in the rock and this presented several problems. Most worms were obtained in pieces since they either broke in two when the rock was split with hammer and chisel or they broke upon removal from their burrows with forceps. Several whole specimens were found on the surface of the rock but were so fragile that they could not be picked up with the forceps without breaking them.

The fragility of the worms proposed a problem in the quantitative analysis in that there were many segments and few whole worms. Quite a few worms were the same size and it could not be determined which head and segments went together. It was decided to count the heads and then obtain a volume of worms by displacement of a liquid, thus giving two measurements.

A few pieces of live coral were obtained which contained tube building polychaetes of the Family Serpulidae.

MOLLUSCA

Molluska were present both as infauna and epifauna. The infauna mollusks, those boring into the coral, composed 62% of one total number collected and were predominantly species of Lithopage and a few Spengleria. These mollusks were found in dead coral rock which had a low mud content, but not in the live corals. Numerous burrows, either empty or with the empty shell, were found in the coral rock which contained mud. The empty shells sometimes appeared as if they were still alive but when the valves were opened they contained only the mud. Only live mollusks were counted and preserved.

The epifauna mollusk population was dominated by a species of Barbatia, with both Arca and Spondylus being present in equal amounts. Spondylus, the "spiny oyster," and was considered epifauna, even though it was permanently attached to the substrate, since it sits above the substrate as opposed to burrowing into it, as do the species of Lithophaga.

ARTHROPODA

The arthropods found in this sampling program were predominantly crabs (118) and shrimp (135). Smaller numbers of stomatopods (15) and amphipods (16) were found. All of the specimens collected would be considered small and most would be classified as epifauna. The Axiidae shrimp could be classified as infauna for they were found in burrows in the coral rock.

ECHINODERMS

The echinoderm population was dominated by the Ophiuroidea or brittle stars (92.6%). Other groups occuring were the echinoids or sea urchins (4.32%), the crinoids or sea lilies (1.85%), and the Asteroidea or true starfish (1.23%).

ALGAE

Although the term algae includes more than one phylum, they have been combined here since the phyla are too similar for non-algologists to separate. Approximately 75% of the algae were Rhodophyta, red algae, and the remaining 25% predominantly Chlorophyta or green algae. Almost all of the algae are calcareous and 75% are encrusting or growing close to the substrata. Most of the surface rock removed from the reef was covered with algae to various degrees. The volume of algae shown in the table does not necessarily reflect the coverage since one large non-encrusting alga almost doubles the volume.

CONCLUSION

It is the opinion of the author that sufficient samples have been taken to give a general picture of the epifauna, infauna, and flora of the reef. The picture will become clearer as the individual species are identified and representatives of the minor phyla recognized. This collection will serve as a basis for comparison with the collection made after the outfall system is installed and functioning.

APPENDIX C

ECOLOGICAL CONSIDERATIONS FROM MICROBIOLOGIC STUDIES

Dr. James B. Lackey

At this time it seems worthwhile to look at the implications developed thus far in the microbiologic studies. Suspended protozoa and microscopic algae (plankton) are perhaps the quickest to respond to changes in the quality of water and are easiest from which to harvest a representative sample. Therefore studies have concentrated on them rather than on rotifera or copepods.

Lines of Study

The first procedure was to make a qualitative and quantitative study of what organisms were present in the various areas. This is being done by taking surface samples (0-1 meter) in transects from the beaches to the Gulf Stream. Along shore (surf) samples are also collected. In part these are preserved with formalin for later examination and in part they are examined alive.

Results of this work have shown a fairly long list of species, and very few organisms per liter. There is a great discrepancy between the numbers of small organisms, 2 micron to 150 micron in size, and the numbers of large diatoms, dinoflagellates and ciliates more than 150 micron overall. Comparison of numbers in 20 liters of such water and a towing straining many liters of water indicates that the large forms are actually very few in number per liter of water. This routine check will be maintained on a yearly basis to learn if there is an annual succession.

A second procedure is to study the organisms in the sediment-water interface. These should better reflect changes in water or sediment qualities, because they are not swept away, but are continuously exposed to sewage being dispersed in the area. This is a new field of work, especially at depths of down to 100 feet, and is yielding many unfamiliar species. Many

of these are probably new, and are not only of practical, but of academic interest. Particularly interesting is the large number of variable diatoms at these depths, indicating ability to fare well in reduced light.

It appears informative also to plant slide holders at various depths and various degrees of nearness to outfalls. These quickly acquire a population, initially of small flagellates (after bacteria), then diatoms, then other organisms. Bringing these into the laboratory after various times of exposure - 24, 48, 72 hours - affords one more way of checking on what organisms are favored by clean water, and which ones react positively to polluted water. The slides are bought in with their organisms alive, in plastic bags, or containers such as coplin jars. This is one of the many advantages derived from having qualified divers who know how to handle planting and recovery.

The findings thus far relative to the sparse plankton population and the more abundant sediment-water interface population necessitate chemical studies which show the fate of the sewage - how much is dispersed at once, how much is incorporated into sediments, and how much is incorporated into organisms.

Interesting side problems arise also, such as the ability of filamentous algae to compact or make firm the sandy bottom. Some study of this phenomenon might well disclose facts concerning stabilization of the bottom in sandy areas.

APPENDIX C

PROGRESS REPORT
8-29-67 to 9-2-67

Dr. James B. Lackey

One series of plankton samples was collected at one mile intervals along the foreshore, Deerfield Beach and north. A second set was collected from the Inlet to the boil over the Pompano outfall. These were analyzed qualitatively and quantitatively. These contained 44 and 48 species respectively There were one or two unusual species, but the rest were species which I have come to regard as common or ubiquitous for inshore waters. The species were a well mixed group with diatoms and dinoflagellates predominating. As a species list they indicated no pollution or enrichment of the area waters. Green Euglenophyceae were almost lacking.

Quantitatively, numbers were very low, hardly reaching 100 cells per ml. This indicates a very low nutrient level since it is the smallest population I have ever encountered.

With this background, I strongly recommend that raw water (containing organisms, particulate matter) be analyzed for total phosphorus, and that filtered aliquots be analyzed for orthophosphate, which represents the amount available for phytoplankton growth.

Two sets of cores were taken, and the interface, as well as the water just above the bottom, was studied. The results were amazing.

At the depths of about 80-100 feet it was anticipated that light would be sufficiently diminished so that chlorophyll containing organisms would be few in kind and number. Actually the numbers of diatoms, dinoflagellates and cryptomonads were much larger than expected, both in kinds of species and in actual numbers, both in the interface and in the water just above the interface. Very few of these were species which were found in the surface plankton, so that there is evidently a different group of bottom dwellers.

The best proof of this is the large number of colorless euglenid and ciliate species. These occur commonly in the interface samples in shallow water especially if the interface is silty, and Great South Bay, N. Y., at Cedar Keys (Gulf Coast) and Cresent Beach (Atlantic above Marineland). However not only were the common ones from such places in the Boca Raton cores, but a whole host of not previously seen species occured.

One light effect was that many species and genera which are green in shallow water were red in these deeper waters. This was especially noticeable in cryptomonads, dinoflagellates and blue green algae. Evidently the development of red pigment helps energy capture from the deeper penetrating components of spectral light.

There was virtually no silt on the bottom. Whether there will be a gradual accumulation in the neighborhood of outfalls should be watched very carefully. Silt can completely change the ecology - it smothers many forms, prevents others from attaching, and is a reservoir from which nutrients may be fed too fast into the overlying water.

The cores in a line extended toward the proposed Boca Raton outfall showed only clean sand. However the surface of this sand was a tenacious mat, difficult to break, or to suck up with a pipette. The binding organism was primarily a large red or pink blue green alga, Lyngbya sp. who long filaments, often several millimeters were interlaced and entangled, and the sheaths of which seemed slightly mucilaginous so that particles adhered. The significance of such growths in leading to bottom compaction needs careful study.

Three organisms - a Volvocale, a Cryptomonad and a blue green alga occurred in sufficient numbers, and are so new to me that I am having them drawn, and am checking the literature. I regard them as new species. Many others, new

to me, were seen, but either in too few numbers, or not sufficiently studied. Nevertheless I am sure that this study of interfaces in cores from deep waters is going to yield a rich new taxonomic group, and some new concepts in ecology.

APPENDIX C

PROGRESS REPORT
October 8, 1967

Dr. James B. Lackey

The previously taken and preserved plankton samples were analyzed between the visit of 8-28-67 and this visit and showed a very small plankton population, few in number of species, and few in total density. Diatoms and small dinoflagellates predominated, although small green flagellates and zooflagellates of 3-8 micron size were common, though not abundant.

There was nothing in this biota to suggest any organic content, recent or remote, or to indicate as much as .5 microgram atom of PO_4. In other words, no evidence of sewage in the area.

Plankton samples taken during the week of October 8 and examined alive, further emphasized this conclusion.

Because it was felt large forms (300 - 1000) might be missed in centrifuging 100 mls, plankton net tows were made in the Gulf Stream, and also closer inshore. These produced large diatoms (Coscinodiscus, Biddulphia); many species of plankton diatoms; large dinoflagellates (Ceratium, Peridinium depressum, Ceratocorys); many Radiolaria and Actinaria; many copepods, worm, mollusk, crustacean and chaetognath larvae. While these are of much academic interest, they actually represent only a sparse population, because of the large volume of water filtered.

All organisms, except bacteria, in 1 ml and 100 mls of Gulf Stream water were counted and in 200 mls only one large organism (Goniodoma, a dinoflagellate) about 200 was found. Total numbers per ml were about 5-10 organisms. If 500/ml are accepted as a bloom, this water had a very sparse population.

As a further check on this it is requested that 20 liters each of Gulf Stream and inshore water be preserved, sedimented and counted. Such inform-

ation will be highly useful, if the increasing volume of sewage from Boca Raton and Hollywood produces any effect - or for that matter, especially if it fails to.

The core interfaces continue to be of extreme academic interest in the number of not known or not-heretofore seen organisms. In my estimation these merit an intensive study as to their systematics. This would be a side issue from the stated purpose of the study.

These core interfaces also bring out some ecologic problems:

a. Diatom populations, even in 100 feet of water, are large, 12,000 - 18,000 per ml of interface material. Whence comes their fertilizer, especially in a column of pure sand? What will happen if sewage silt is deposited in the sand around the outfalls? Some of the sand is very coarse and could receive finely divided sewage solids into its interstices.

b. Populations of ciliates and colorless euglenids which are holozoic and saprozoic are also abundant in the core interfaces, and would quickly respond to settled out sewage.

c. Dinoflagellates are principally sand dwelling types such as Amphidinium herdmanni. Most of them are well known.

d. Almost all the blue green algae are pink to deep red. Yentsch, the new biologist at Nova Sc. is interested in them.

There are a number of new or undescribed organisms in the cores. These will be figured and described as time allows.

There is no doubt that the filamentous blue green algae and a general mixture of other organisms can and do protect the sand in large patches from current blowout. Presumably a stable bottom is the most productive one. Since blue greens are one of the first to show a growth response to sewage, this might be a factor in stable bottom development. The photographs of

Dr. McAllister sampling one of these patches, Figure 8, are quite enlightening, and I believe even at this stage, a short paper could be worked up. I'd like to discuss it in extenso on my next visit.

APPENDIX C

PROGRESS REPORT
January 8-10, 1968

Dr. James B. Lackey

On January 8-10, 1968, one set of unkilled samples from the surf in Deerfield Beach - Boca Raton, was analyzed quantitatively and qualitatively. A very strong onshore (northeast) wind was blowing and it was thought the plankton organisms might be present in more abundance, possibly from the Gulf Stream, and also from the stirred-up inshore interface material. No such increase was present. Instead the organisms were even more sparse than previously. The obvious explanation is that this stretch of sand is simply low in nutrients, and therefore unproductive. It received water from two inlets in this expanse, but no other source of land contributed fertilizer exists. If the inlets add nutrients, these are at once greatly diluted.

Preserved samples from two surface transects, beach to Gulf Stream were also analyzed. In these two the microorganisms were so few they were estimated in numbers in 10 mls, rather than per ml. If this paucity is observed over several months duration, the only inference is that this water is very poor - i.e., it is of excellent recreational quality, but poor for fish.

One item of interest was the relatively large quantity of fibers, which appeared to be cellulose, in all these samples. I have not encountered this material elsewhere, except an occasional fiber. If this material is derived from paper brought in by sewage, it could eventually accumulate and cause a psychological nuisance condition. Dr. McAllister also points out that it might be an indicator for sewage, if such an origin could be proved.

Slide holders were brought down, to be set at various depths and locations, to determine the rate and kinds of microbiotic organisms accumulating within 24 - 72 hours. These will be used during succeeding trips.

APPENDIX C

PROGRESS REPORT
2-5-68 to 2-10-68

Dr. James B. Lackey

Transect, surface water, shore to Gulf Stream, Pompano Beach.

On this transect, 7 samples yielded 56 species of plankton algae and protozoa. The species list is therefore of reasonable length, considering that this is a winter sample. (a winter sample here, however, may be collected at 70° F., which is a better temperature environment than most summer samples at La Jolla enjoy.) Since the hours of daylight are not greatly different here and at La Jolla, the latter being much more productive in numbers per ml, the conclusion is that this Florida water is very poor in nutrients. Further evidence is adduced from the intracoastal waterway sample, which had 1250 organisms per ml, whereas the ocean samples never got to as high as 100 per ml. This is ample evidence that we must analyze for at least NO_3 and PO_4 in these ocean samples.

These samples compare closely to those in the nearshore waters of Cutter Point and Turkey Point in South Biscayne Bay. These are open waters, sampled about two weeks later. A similar set of samples from Port Sutton, Hillsborough Bay however, showed several thousand per ml. Many of these were filaments of Skeletonema (Diatom) each about 10 cells in length.

Some of these were species new to me and some were unusual in that I very seldom found them previously. It begins to look as if certain species are endemic in certain areas, and rare elsewhere.

A start was made on bringing back slides after 24 hours. Slides in 52 feet of water quickly acquired a good diatom population, but other species also. Counts of 156 square millimeters showed as many as 356 organisms,

including a number which have not shown up as suspended forms. This large number at 52 feet is surprising - as many there as at 30 feet. However this examination (only four slides) is purely preliminary. It is promising however.

The few cores brought up were pure sand. Nevertheless they showed a large species list, including one large colorless and very distinctive euglenid. This work too needs careful pursuit, and refinement of technique.

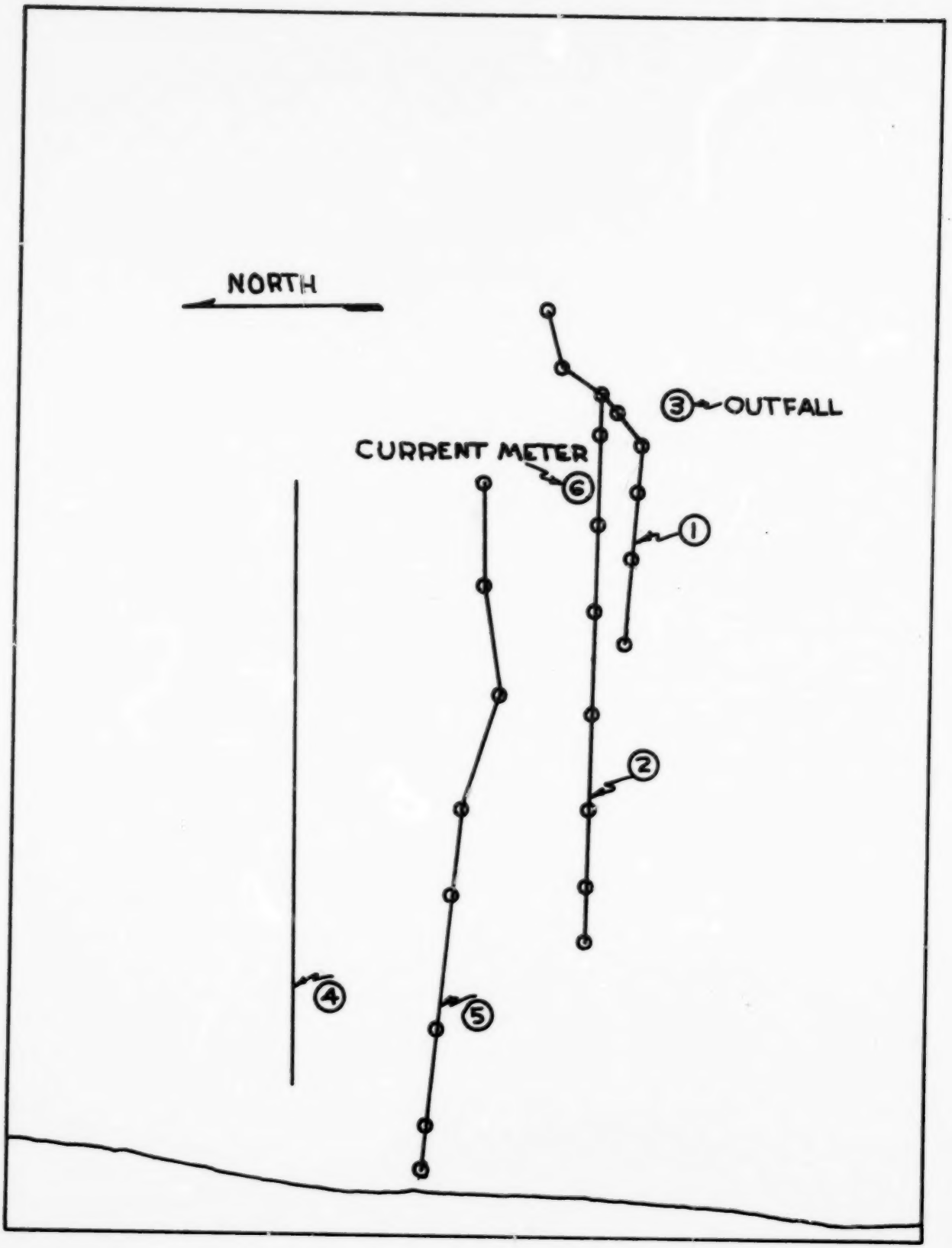


FIG. 25 DR. LACKEY'S SAMPLES - POMPANO BEACH

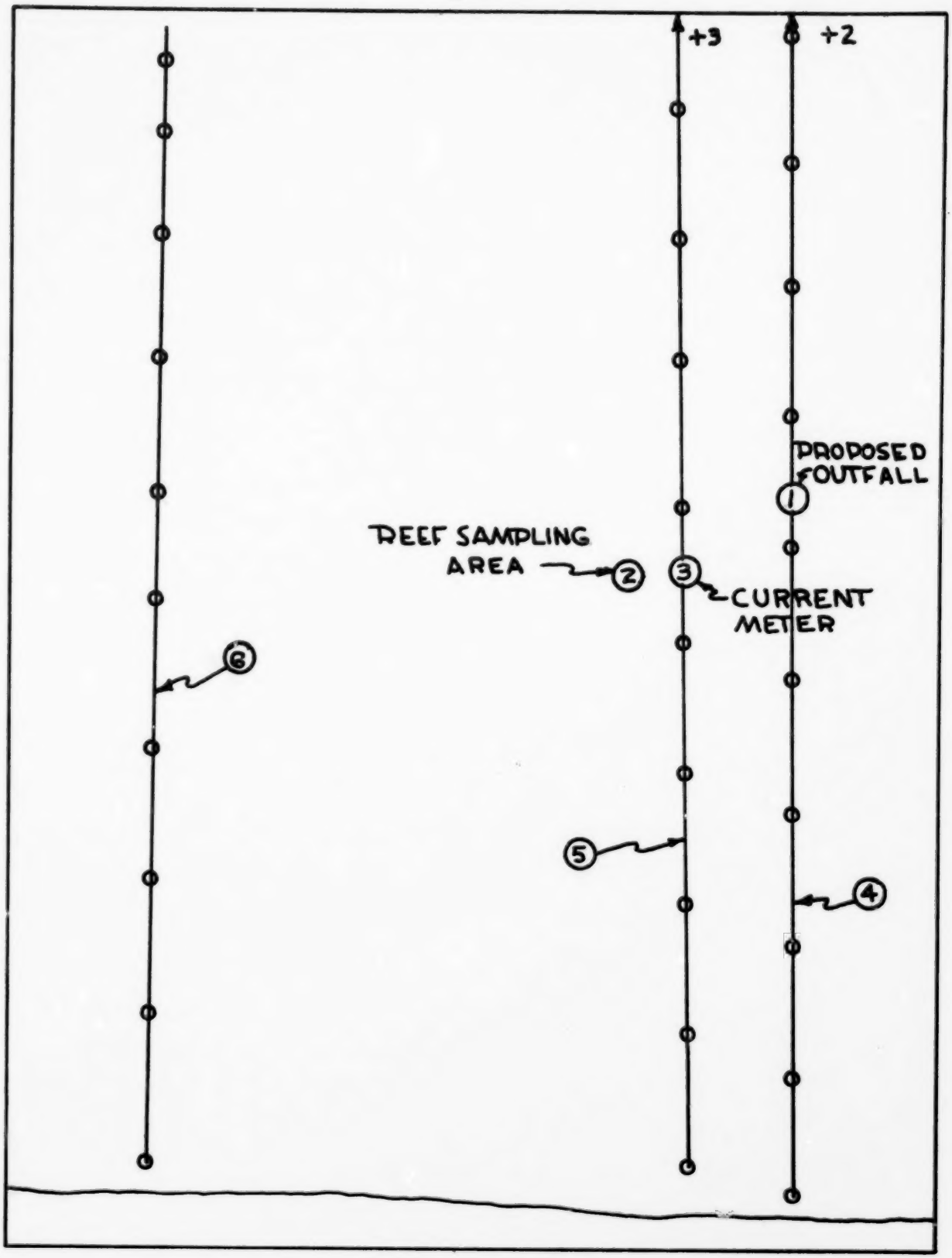


FIG. 26 DR. LACKEY'S SAMPLES - BOCA RATON

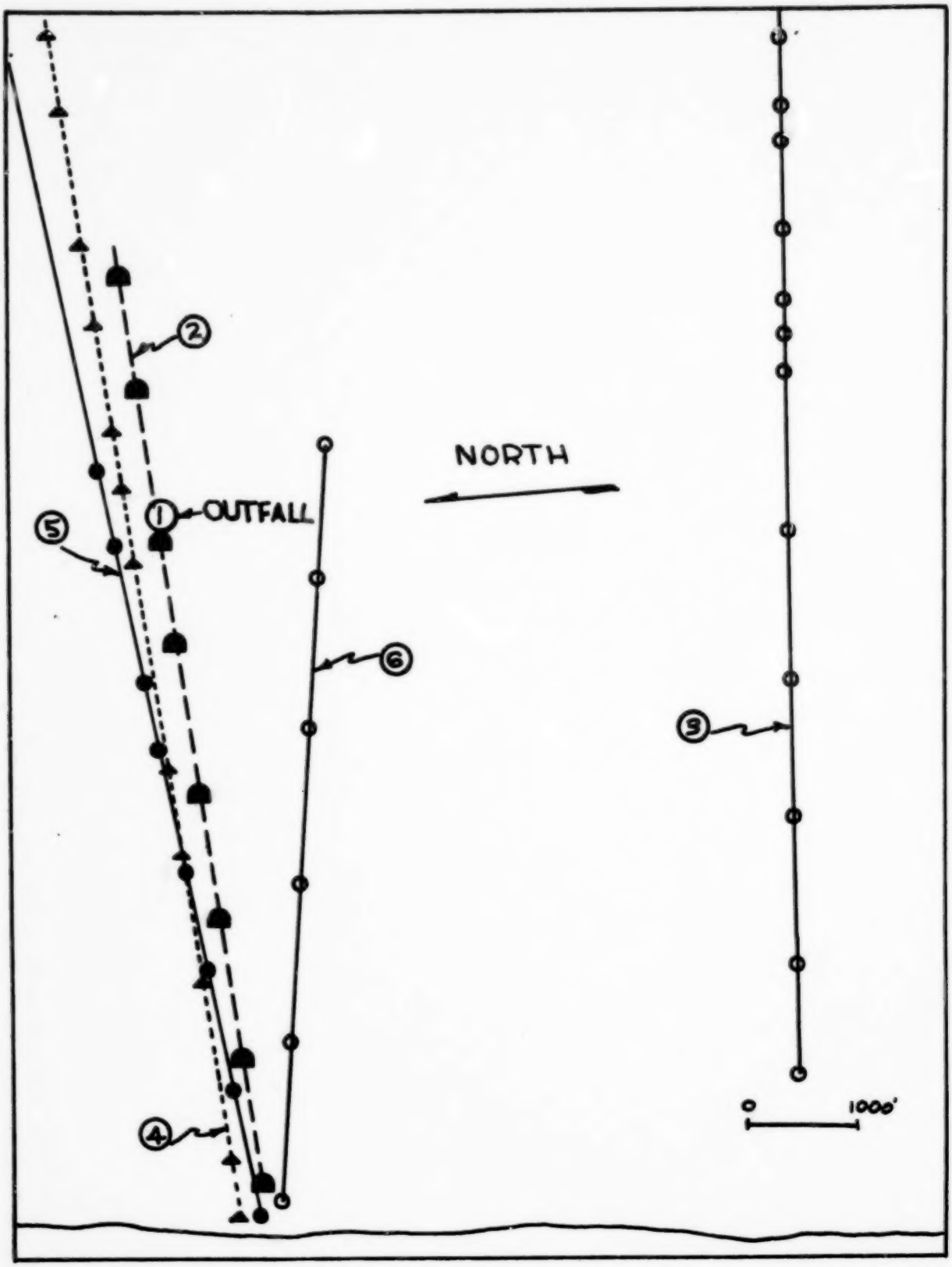


FIG. 27 DR. LACKEY'S SAMPLES - DELRAY BEACH

SAMPLE SERIES NUMBER	DATE	NUMBER OF SAMPLES TAKEN	TYPE SAMPLES TAKEN	LOCATION
BOCA RATON				
1	8/28/67	10	Plankton	
2	9/1/67	4	Plankton	Reef Sampling Area
3	10/10/67	3	Plankton	Current Meter
4	10/11/67	12	Plankton	Pavilion to 7650' off shore
5	1/11/68	12	Plankton	Beach to 9900' off shore
6	2/20/68	10	Plankton	Beach to 7400' off shore
DELRAY BEACH				
1	7/28/67		Plankton	Boil
2	8/24/67	8	Plankton	
1 *	10/10/67	4	Cores	Outfall
3	10/12/67	12	Plankton	
4	11/16/67	12	Plankton	
5	12/18/67	8	Plankton	
6	2/22/68	6	Plankton	
POMPANO BEACH				
1	7/31/67	8	Plankton	
2	8/14/67	8	Plankton	
3	8/30/67	4	Cores	Outfall
3 *	8/31/67	4	Cores	Outfall
4	10/13/67		Plankton	
5	8/21/67	8	Plankton	
6	2/6/68	4	Slides	Current Meter
6 *	2/13/68	8	Slides	Current Meter

See Figure 26

See Figure 27

See Figure 25

* Denotes sample series at one location at different times.

TABLE 15 DATA RE DR. LACKEYS SAMPLES

APPENDIX D

LATE ADDENDUM

Additions to the preceeding report have been made since it went to press. These are included below:

Figures 28, 29, and 30 show the distribution of random coliform determinations in the three major areas of interest. The three figures were prepared by Mr. Lee Reed of the Palm Beach County Board of Health. Since these were random samplings, it was fortuitous if some fell in the outfall boil and plume. Later samplings have been concentrated in the outfall area.

Figures 31, 32, and 33 represent 1000 foot wide zones from the beach seaward, and the average speed of the current in each zone as shown by our current cross studies. The low percentage of readings close to the beach, and from 9 to 10,000 feet offshore, have resulted in some bias, particularly offshore at Boca Raton. Nevertheless, the overall current velocities are rather well shown to decrease, from the outer shelf toward the beach, in all three areas.

The concentration of samples in each case is in the thousand foot wide zones closest to the outfall, at 5, 6, 7, and 8000 feet off the beach.

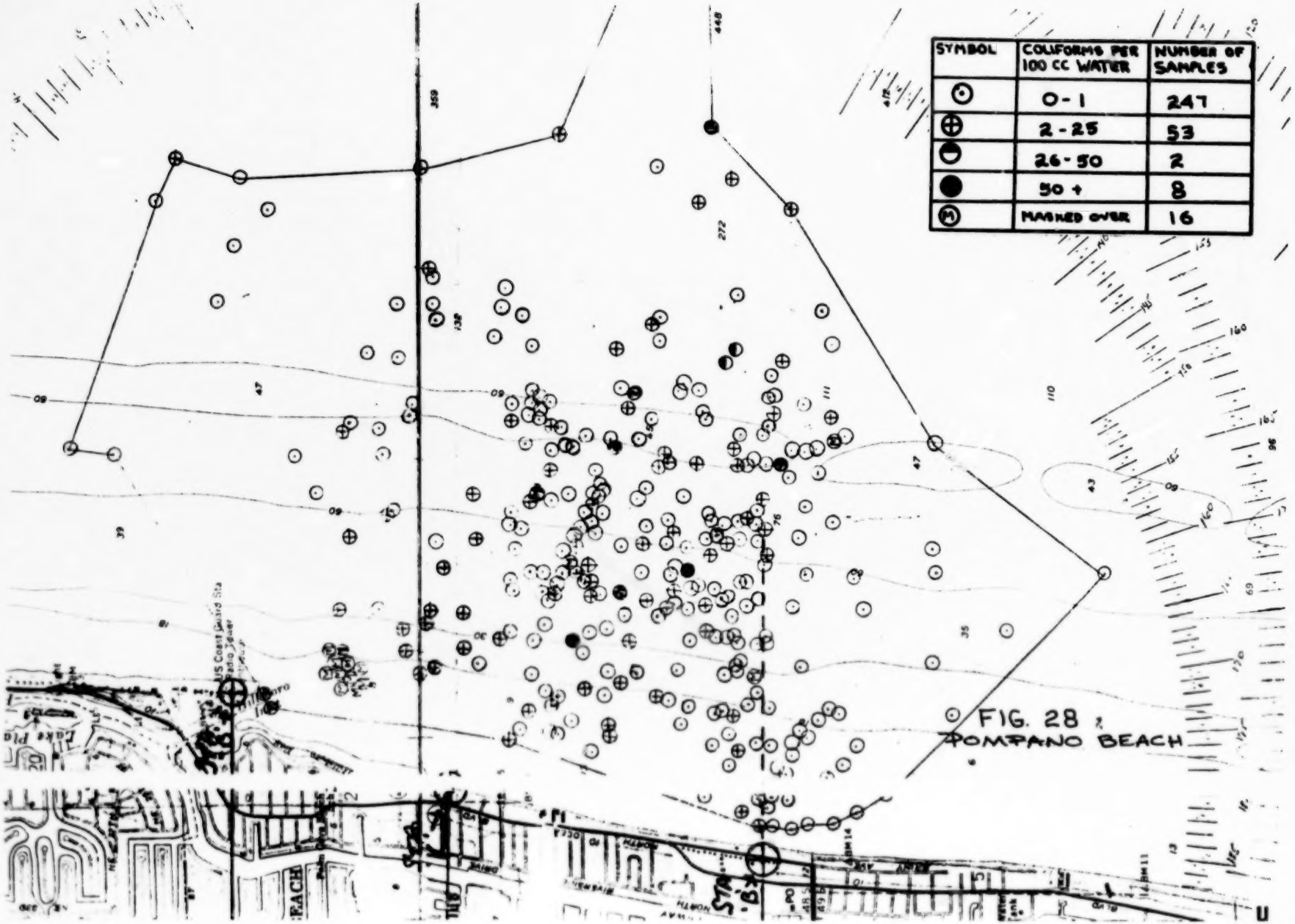


FIG. 28
POMPANO BEACH

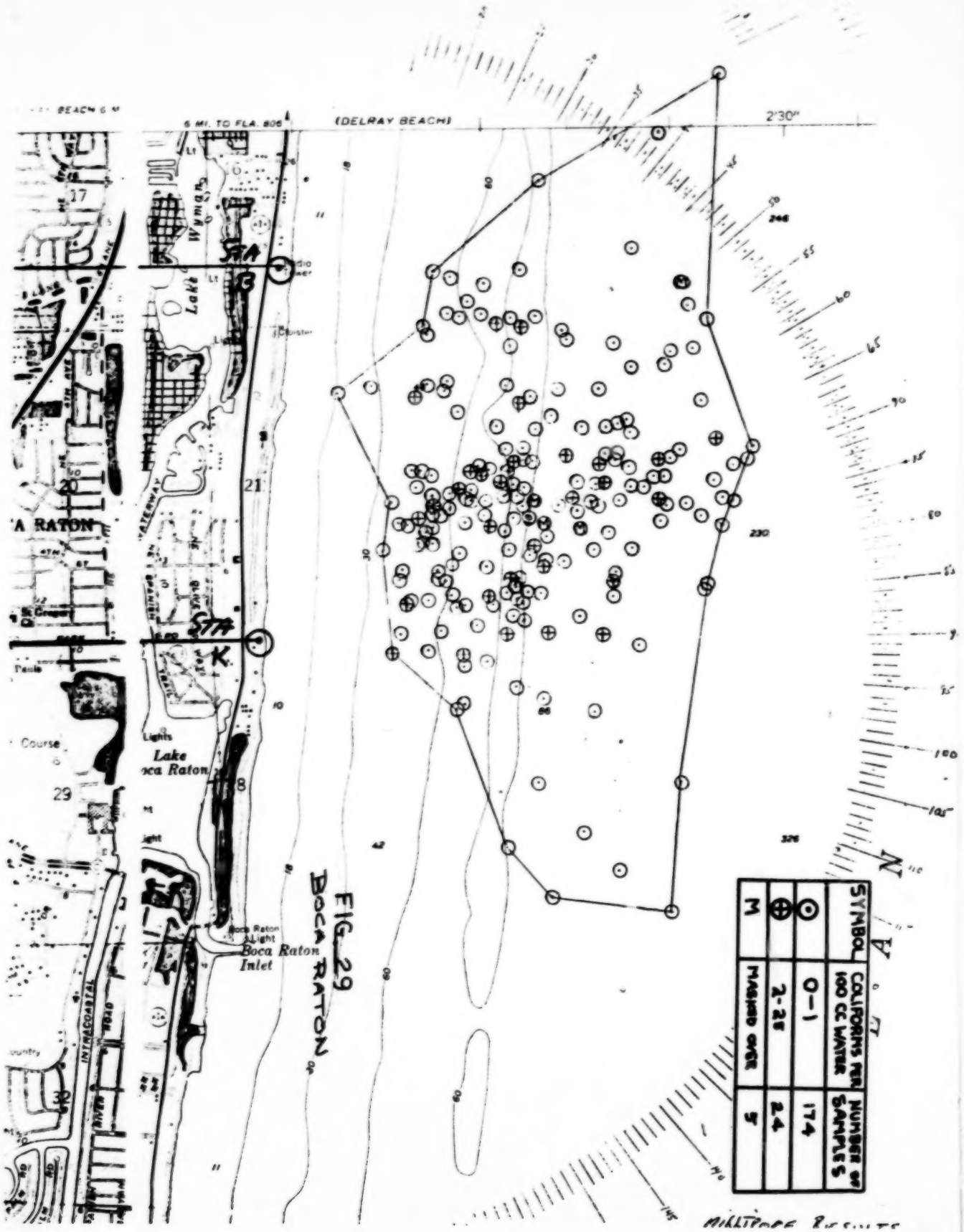


FIG. 29
BOCA RATON

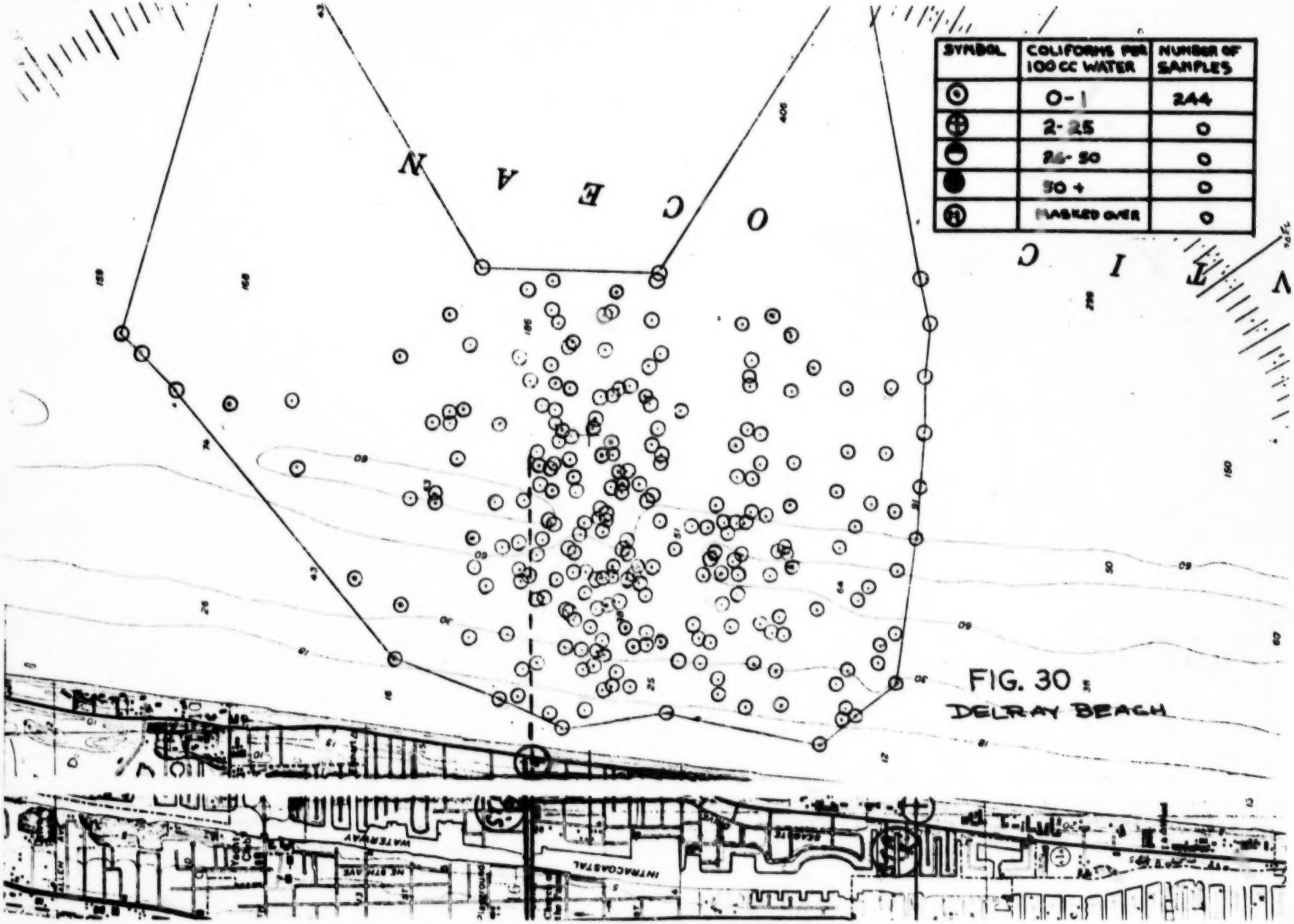


FIG. 30
DELRAY BEACH

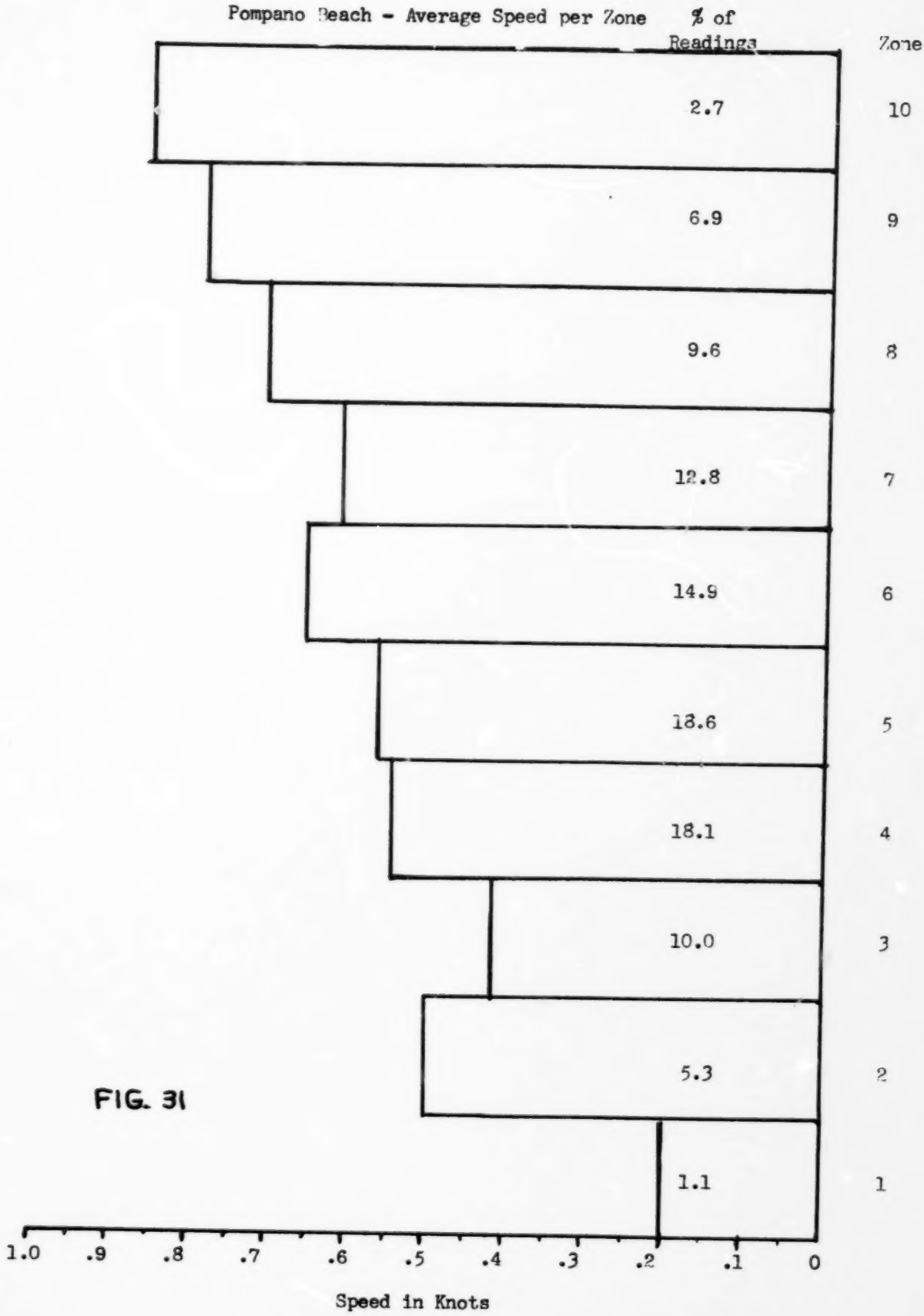

Pompano Beach - Average Speed per Zone
% of Readings
Zone
2.7
10
6.9
9
9.6
8
12.8
7
14.9
6
13.6
5
18.1
4
10.0
3
5.3
2
1.1
1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Speed in Knots

FIG. 31

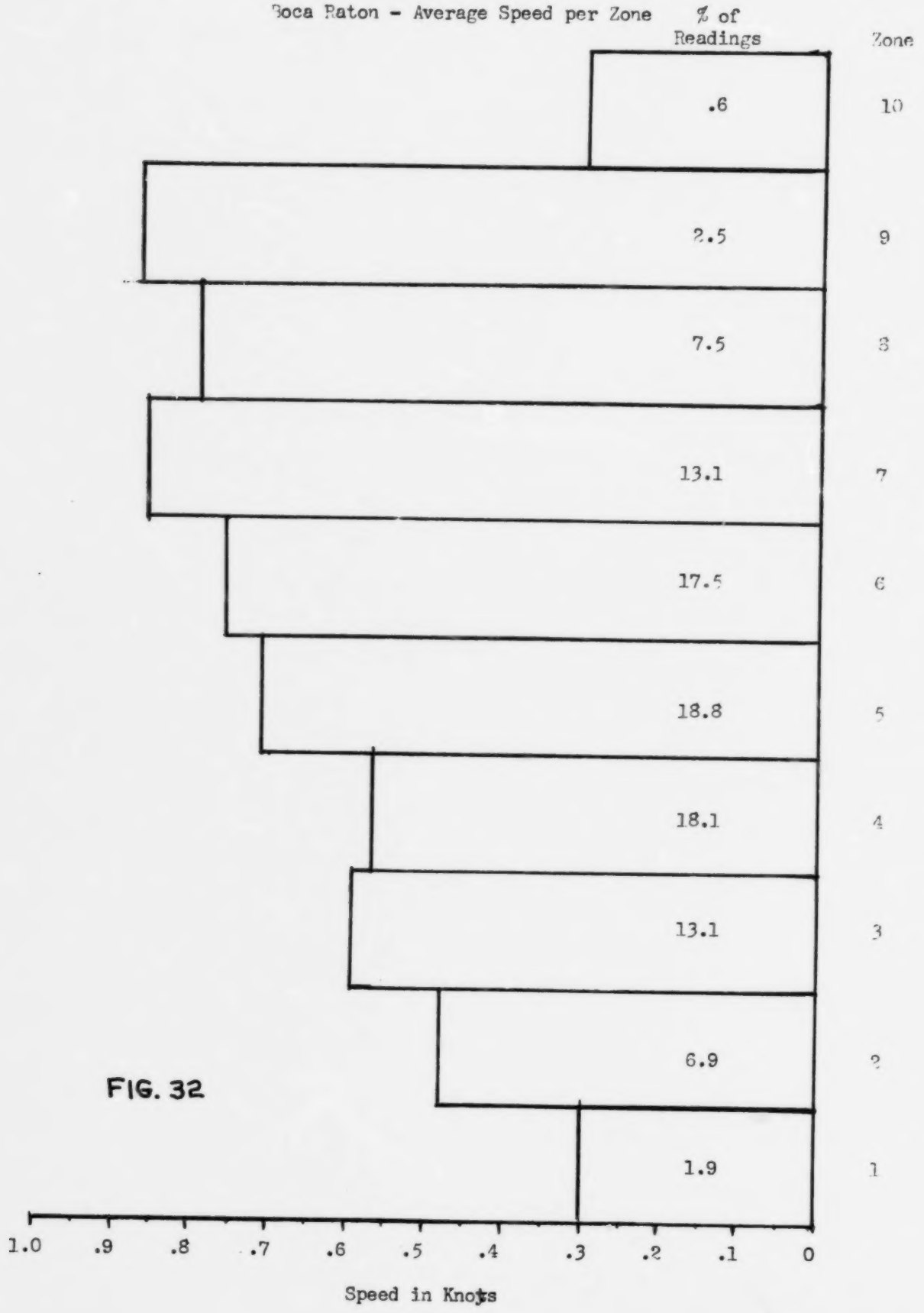

Boca Raton - Average Speed per Zone
% of Readings
Zone
.6
10
2.5
9
7.5
8
13.1
7
17.5
6
18.8
5
18.1
4
13.1
3
6.9
2
1.9
1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Speed in Knots

FIG. 32

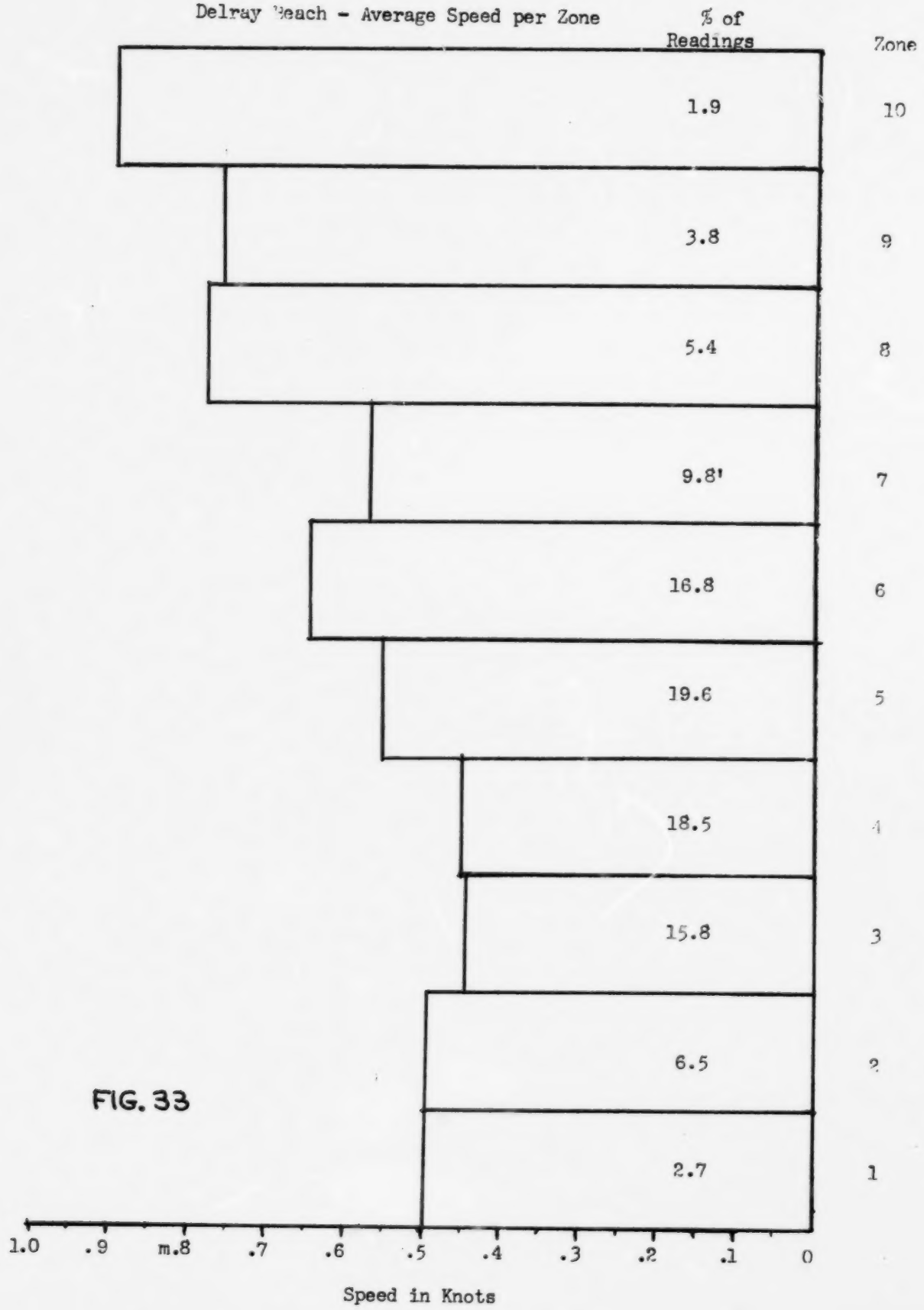

Delray Beach - Average Speed per Zone
% of Readings
Zone
1.9
10
3.8
9
5.4
8
9.8'
7
16.8
6
19.6
5
18.5
4
15.8
3
6.5
2
2.7
1
1.0
.9
m.8
.7
.6
.5
.4
.3
.2
.1
0
Speed in Knots

FIG. 33

PROJECT PERSONNEL

NAME	PERIOD OF EMPLOYMENT	PERCENTAGE OF TIME	TITLE
Raymond F. McAllister	April 1, 1967 to present	20%	Project Director and Chief Investigator
James B. Lackey	April 1, 1967 to present	25%	Co-Investigator
Edward D. DeLamater	April 1, 1967 to present	20%	Co-Investigator
Eugene A. Robinson	April 1, 1967 to present	20%	Financial Advisor
Robert A. Rosof	April 15, 1967 to present	100%	Technical Supervisor
Kenneth Richard Stark	April 15, 1967 to February 15, 1968	100%	Marine Technician
Edward Harper, III	May 22, 1967 to present	100%	Marine Technician
Jay Hayes Bronson	July 17, 1967 to present	100%	Marine Technician
Terry Lee Davis	August 14, 1967 to present	100%	Marine Technician
Charles Thomas Ott	January 8, 1968 to present	100%	Marine Technician
Kent Demmler Wilson	February 22, 1968 to present	100%	Marine Technician
William Runyon Gonzalez	April 15, 1967 to November 30, 1967	Part-time	Student
Charlotte Lynn Haynes	May 15, 1967 to July 15, 1967	Part-time	Student
Keith McAllister	June 5, 1967 to present	Part-time	Student
Kenneth R. Cletzer	June 15, 1967 to July 15, 1967	Part-time	Student
Douglas Arland Briggs	July 24, 1967 to present	Part-time	Student

Ernest Michael Twist	September 15, 1967 to present	Part-time	Student
Richard Arthur Halsey	October 16, 1967 to December 15, 1967	Part-time	Student
Donald Evert Laaksonen	December 12, 1967 to December 30, 1967	Part-time	Student
Herbert J. Glattli	February 21, 1968 to present	Part-time (as needed)	Marine Technician
Edwin O. Coggin	February 22, 1968 to present	Part-time (as needed)	Marine Technician
James B. Davidson, Jr.	July 24, 1967 to present	Part-time (as needed)	Student